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FEDERAL MACHINERY NOISE RESEARCH, DEVELOPMENT, AND DEMOSTRATION: FY 73 - FY 75

Environmental Protection Agency
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May 1975

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Federal Machinery Noise Research, Development and Demonstration: FY 73 - FY 75

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Prepared by

Interagency Machinery Noise Research Panel

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1.0 INTRODUCTION

EPA has established four noise research panels consisting of representatives from Government departments and agencies to provide informational exchange, a forum for interagency discussion, and advice to aid EPA in its role as the coordinator of Federal noise research in accordance with the Noise Control Act of 1972. The panels and panel membership reflect the major thrusts of the Federal noise research programs as follows:

Noise Research Panel	Current Agency Membership*
Aircraft	NASA, DOT, DOD, HUD, DOC, EPA
Surface Vehicles	DOT, HUD, DOD, DOC (NBS), EPA
Noise Effects	HEW (NINDS, NIOSH, NIEHS), DOT, NSF, HUD, NASA, DOD, DOL, DOC(NBS), EPA
Machinery**	HEW (NIOSH), DOI (Bureau of Mines), DOT, DOD, DOL, DOC,(NBS), EPA

These panels provide the formal mechanisms for interagency consideration review and assessment of research in the four technical areas. The primary functions of the panels in their respective areas are:

- Review and assessment of the state of science and technology relating to noise.
- Review and assessment of the status of noise research and technology development.
- Identification of technology gaps and research needs.
- Preparation of recommendations concerning ongoing research activities.
- Recommendations of noise research programs and projects and methods for accomplishments.

For the purposes of this report, the term "machinery" includes all mechanical devices not classified as aircraft or surface vehicles.

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* Glossary of Agency Acronyms in Appendix A.
** List of Machinery Panel Members in Appendix B.

Machinery then means not only industrial machinery, but also household appliances, toys, some construction equipment, electronic devices and equipment, office machines, gardening and power tools, furnaces and air conditioners. As the panel is concerned with noise reduction in general, this report will also deal with research on structural transmission of noise and building acoustics, and the use of noise control materials.

1.1 PURPOSE AND SCOPE

This is the first report prepared by the Machinery Noise Research Panel. It presents a summary of current Federal programs and projects which seek to understand and control machinery noise. To view these Federal efforts from a proper perspective, the report also addresses:

- sources of machinery noise
- impact of machinery noise
- private sector efforts in machinery noise RD&D

This report does not address:

- the state of technology for controlling machinery noise
- research needs in machinery noise
- adequacy of current Federal RD&D
- role of the Federal Government in machinery noise RD&D

This document also will be used by the Environmental Protection Agency in preparing a report to satisfy Section 4(c)(3) of the Noise Control Act of 1972. EPA is required to report on the status and progress of Federal activities relating to noise research and control and to assess the contribution of such activities to the Federal Government's overall efforts to control noise.

Activity for fiscal year (FY) 1974 is emphasized, program continuation through FY 1975 is noted where possible, and funding and work carried out during FY 1973 is reported. The data on which the report is based came from two sources: Agencies' responses to a 1974 request from EPA on Federal noise activities and information supplied by the panel members in 1974. Although the data are current as of the end of 1974 and fairly complete, there are variations in the ways agencies calculate the costs of overhead for their in-house research. Thus, comparisons between agencies' reported fiscal data are not exact.

The fiscal data are also incomplete. First, much of the DOD Research Development and Demonstration (RD&D) on machinery noise is classified for national security reasons. However, general research areas and the extent of overall funding is reported. Secondly, NSF carries out research only through unsolicited grants. Thus, it is impossible for NSF to predict what research proposals may be received and funded.

Conclusions and recommendations made in this report are the collective opinions of the panel members and do not necessarily represent their agencies' policies.

1.2 SOURCES OF MACHINERY NOISE

Considering the definition of machinery used in this report, there are literally countless sources of machinery noise to which people are exposed. Machinery is found in almost every human environment. In general, exposures in the industrial occupational environment are the most severe in terms of both level and duration. Examples of some machinery noise levels in the worst industries are shown in Table 1.1. It should be noted that these levels are only representative. Many parameters, such as manufacturer, working material, size of the machinery, etc. can affect the noise level. Appendix E, which makes no attempt to be all-inclusive, identifies 357 machines in 20 industries.

Machinery noise also occurs in the home, in hospitals, in office and residential buildings, and in the community. Some general categories of sources include appliances, building equipment, power tools, and toys. Examples of these sources and their noise levels are shown in Table 1.2.

As specified in the Section 5 of the Noise Control Act of 1972 (Public Law 92-574, 86 Stat. 1234), the first step toward promulgation of noise standards for new products is identification of those products which are major sources of noise. On June 21, 1974, EPA designated portable air compressors rated above 2.124 cubic meters (75 cubic feet) per minute and medium and heavy duty trucks as major sources of noise. The designation was based on "air compressors as the major source of sound energy and the most widely used product among pieces of construction equipment contributing to construction site noise" (after medium and heavy duty trucks). (Ref. 1)* The designation was based on environmental noise impact and not occupational noise impact, which is principally concerned with hearing loss.

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* For references, see Section 5.0

Table 1.1 EXAMPLES OF INDUSTRIAL MACHINERY NOISE SOURCES

INDUSTRY	TYPE SOURCE	NOISE LEVEL (dBA)*
Construction Equipment 15.2 meters (50 feet)	Air Compressor	81
	Jack Hammer	88
	Generator	78
	Pile Driver	101
	Crane-Derrick	88
	Back Hoe	85
	Rock Drill	98
	Pneumatic Tools	85
Metal Working Machinery (Operator position)	Drop Hammers	111
	Punch Presses	107
	Riveting Machines	117
	Chipping Machines	127
Wood Working Machinery (Operator position)	Planers	108
	Saws	111
	Molders	99
	Tenoners	95
Textile Manufacturing Machinery (Operator position)	Looms	102
	Combing Machines	95
	Reducing Machines	96
	Bleaching, Dying and Finishing Machinery	100

NOTE: Levels are only representative.

* References and a more comprehensive list are found in Appendices E and F.

Table 1.2 OTHER MACHINERY NOISE SOURCES

CATEGORY	TYPE SOURCE	NOISE LEVEL (dBA)
Home Appliance .985 meters (3 feet) (Ref. 2)	Vacuum Cleaner	73
	Clothes Drier	63
	Dish Washer	65
	Shop Tools	83
	Sewing Machine	73
	Waste Disposal	78
	Food Blender	75
	Electric Can Opener	66
	Air Conditioner	58
I.C. Engine Powered Tools 15.2 meters (50 feet) (Ref. 3)	Lawn Mowers	72
	Chain Saws	83
	Snow Blowers	85
	Lawn Edges	78
	Tillers	69
	Garden Tractors	75

NOTE: Levels are only representative.

1.3 IMPACT OF MACHINERY NOISE

General agreement exists that hearing loss is the most severe health effect of long term exposure to noise. EPA has estimated that as many as 25 million American workers have been exposed to noise potentially hazardous to their hearing. Noise from machinery sources in industry has been shown to affect work performance, cause short term physiological changes, and interfere with warning signals. (Ref. 4)

Estimates of the costs for reducing occupational noise to levels of marginal protection against hearing loss run into billions of dollars. (Ref. 5) However, these estimates are crude at best and little data exist to adequately define the extent of the machinery noise problem in the occupational environment and to assess the availability and cost of technology for industrial noise control. The available data do indicate that the problem is complex in terms of the vast number of different machines in use, severe in terms of numbers of people exposed to hazardous levels of noise, and costly in terms of available control technology.

Although noise exposures in industrial environments are the most severe, machinery sources can impact significantly in other environments. Machinery noise may disturb sleep, annoy, interfere with activities, and contribute to fatigue and irritation in residential, hospital, office, or recreational environments. (Ref. 4) EPA has estimated that 13 million people presently reside in areas where noise levels exceed those potentially hazardous to hearing.

The vast number of machines involved, the large number of people affected, and the costs involved in control of machinery noise would suggest the need for a concerted Federal involvement in this area.

1.4 PRIVATE SECTOR EFFORTS IN MACHINERY NOISE RD&D

The sheer magnitude of the noise sources and levels in industrial machinery alone suggest that much research would be going on in the private sector to develop more cost effective noise control technology. The Machinery Noise Research Panel felt than an indication of the RD&D being carried out by industry was needed to determine the Federal Government's role in machinery noise RD&D. The panel, however, identified major problems of data acquisition on private sector work due to the proprietary nature of most industry RD&D and the large number of firms. Trade associations were suggested as an initial way of obtaining an indication of machinery noise research supported by industry.

Consequently, a number of trade associations were contacted and a literature search was conducted for the period 1971-1974. The details of the results are reported in Appendices C and D. The conclusions are as follows:

Noise Abatement Research by Trade Associations - Trade associations are not considered a source for large amounts of quantitized data on noise sources, noise levels and noise treatment technology. However, most of the associations are aware of the noise problems within their industries and are keeping abreast of existing and new noise regulations.

Machinery Noise Literature Search - In a literature search which covered the period 1971-1974, 321 publications were identified as pertinent to machinery noise. The abstracts provided virtually no technical information which could be used in assessing noise levels, noise reduction techniques, or effectiveness of the application of control technology. A distribution of over 20 industries showed that seven industries had no publications at all and seven industries had less than ten each. The majority of the publications were either concentrated in the other six industries or could not be classified. It can be concluded that for most industries there is not much public reporting of machinery noise research results.

In summary, it appears that trade associations are not conducting much research on machinery noise and other industry research will most likely be proprietary. The literature search showed that for most industries there were few publications in the period 1971-1974. Therefore, there is not much ongoing private sector research which will produce publicly available machinery noise control technology.

2.0 DESCRIPTION OF FEDERAL MACHINERY NOISE RD&D

Table 2.1 shows that eight Federal agencies, including two components of DOD, are sponsoring machinery noise research. The Navy by far has the largest activity, with about a million dollars per year spent in the machinery noise area. However, the results of this research are classified and thus are not currently publicly available. The other agencies' in FY 74 together spent a total of more than 2 million dollars on machinery noise RD&D. The total Federal effort has been in the range of 2 to 3 million dollars per year and appeared to peak in FY 74. A brief description of each agency's activities is presented below.

2.1 DEPARTMENT OF DEFENSE

The DOD research effort in machinery noise reduction follows the traditional methods of establishing criteria, determining the noise producing mechanisms, and developing techniques to reduce such noise. This effort is supplemented, when reduction of the source itself is not possible, by mitigation through use of structural damping, resilient mounts, and the use of acoustical transmission loss and absorptive materials.

The major DOD effort is in the Department of the Navy, in particular Naval Sea Systems Command. This work addresses the quieting of ships to avoid detection, improve sonar listening, and reduce susceptibility of ships to acoustically actuated weapons and energy detection systems. Other DOD efforts are conducted by the Army on various pieces of military equipment. Various military standards: MIL-STD-740 (Ref. 6), which covers naval machinery; MIL-STD-1474 (Ref. 7), which covers Army Material Command equipment; and MIL-D-008806B (Ref. 8), which covers Air Force equipment aboard aircraft, provide guidance in how to measure noise and standards of acceptability.

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Table 2.1 MACHINERY NOISE RD&D FUNDING BY AGENCY

(Thousands of Dollars)

AGENCY	FY 73	FY 74	FY 75
DOI/Bureau of Mines	337	528	730[1]
DOC/NBS	138	264	265
HEW/NIOSH	16[2]	226	138
NSF	243	356	-
EPA	60	230	100
DOD/USN[3]	-	-	-
DOD/USA	178	490	245[1]
CPSC	0	70	0
USDA	0	20	92
	972	2,184	1,570

[1] Projected

[2] This figure does not reflect $60.5K funded in FY 72 for work done in FY 73.

[3] Navy funding for specific RD&D activities in Machinery Noise cannot be reported for security reasons. However, the total effort in this area is about $1 million each year.

2.1.1 U.S. Navy

In addition to the various military standards mentioned above, noise level requirements are frequently stated in the individual shipbuilding specifications for items of special interest. While the Navy effort is primarily concerned with radiated and sonar self-noise, such effort results in quieter machinery. The principal noise offenders are those associated with propulsion plants. These include internal combustion engines, gears, valves, and auxiliaries such as pumps, motors, generators, etc.

Diesel Engines - The most serious noise producing machinery item is the diesel engine. Noise levels in the vicinity of unquieted diesels as high as 125 dBA are not uncommon. These noises are caused by the exhaust, piston impact, valves and other moving parts. Significant reductions have been obtained as a result of research in muffler design, use of heavier engine parts, lining of intake ducting, acoustical cladding and enclosures. Because noise levels generally increase primarily with speed

and to a lesser extent with increase in bore, stroke, and number of cylinders, slower engines are used where feasible.

Hydraulic Systems - Extensive research is being conducted on hydraulic system noise reduction. In addition to the work on specific components such as pumps and valves, studies are being conducted on acoustical filters, flexible pipe connections, pipe hangers, and pipe damping. Handbooks are under development to (a) summarize all physical, acoustical and usage data on flexible pipes and hose connections, and (b) depict the design of noise reducing pipe hangers.

Pneumatic Machinery - Pneumatic machinery is quieted by a combination of damping and careful machining of components.

Rotating Electrical Machinery - Rotating electrical machinery produces noise of three types: mechanical, airflow and magnetic. The mechanical noise can be reduced by careful balancing of the rotors, control of clearances, and lubrication. Brush noise is controlled by using holders of damped material, proper tightening, bearing brushes, polishing of commutators, and correction of eccentricity of slip rings or commutators. Balancing rings are used to facilitate balancing. Air flow noise is essentially fan noise and is discussed in a following paragraph. Magnetic noise, which is caused by variations in the magnetic path, can also be reduced by careful balancing.

Electronic Equipment - Generally noise from electronic equipment is airflow related. The air flow causes vibration of internal components such as elements on circuit boards as well as the items discussed under fan noise. Electronic cabinets, because of their light weight, are quick to resonate. Research is underway to determine the proper applications of air intake and exhaust mufflers, quiet fans, and damping to reduce this noise source.

Sound Path Isolators - Ideally, noise should be reduced by controlling the source, the component itself. If this cannot be done adequately, there is the problem of transmission by a structureborne path and subsequent reradiation. Structureborne transmission of noise can be reduced by the proper use of resilient mounts and mounting material. Mounts have been developed from various types of distributed isolation materials (DIM) and with capacities up to 4,536 kilograms (10,000 pounds). These are commercially available. Research on mounts is in process to improve the resistance of the material to deterioration from ozone and oil and from very high ambient temperatures. Reduction in structureborne paths is also achieved through the use of structural damping. Damping reduces the amplitude of vibration at the resonant frequency of the structure. Damping materials developed under Navy sponsorship are also widely used in non-Navy applications and are commercially available. Research is continuing to develop damping materials suitable for higher temperatures

and heavier plate. A design handbook is being prepared for damped foundations.

Gas Turbines - Turbine noise results from many sources including unbalance of the rotor, motion of the rotor blades past the stator blades, and flow through the exhaust and intake ducts. Silencing has been achieved through the use of microbalancing of the rotor, damping of the turbine blades, damping of the reduction gear casing, lining of air intake, and use of splitters and septa in the air intake. In addition, acoustical enclosures have been developed to silence the entire turbine. Reductions of 40 to 50 dB have been obtained in the speech interference bands (500, 1,000, 2,000 Hz octave bands).

Compressors - Research is underway to investigate the noise sources associated with compressors and the application of available noise reduction techniques. These include investigation of pulsation dampers, blowdown silencers, and optimum mounting methods.

Fans - Fans used in ventilation systems and other equipment are principal noise producers. Fan noise is generally tonal at the blade passage frequency or one of its harmonics. It is caused by the blades passing close to the machine structure. It can become particularly serious if the housing or the ventilation ductwork is excited to resonance. Research is being conducted in fan blades, and knowledge obtained from pump impeller design is being applied to quiet fan noise.

Gears - Gear noise is characterized by broadband noise with a number of discrete tones. These are the various harmonics of the gear speed, with those corresponding to multiples of the pinion speed frequency and the tooth contact frequency most prominent. Factors which affect the generation of gear noise include unbalance and eccentricity, improper tooth shape and spacing, helix error, improper alignment, deflection under load, lubricant pumping, tooth friction, bearing reaction, etc. Gear noise has been significantly reduced by more precise machining (removal of burrs, grooves, high spots, etc.), care in alignment, and assuring the removal of any foreign material from the lubricant. Research continues through the use of computer analysis. Further reductions in airborne noise levels are anticipated through use of improved damping, case hardening, and the application of transmission loss treatments to the housing.

Valves - Valves are noise sources because abrupt changes in flow contours cause increased turbulence levels. Valve types have been rated in order of increasing noise generation as follows: plug, gate, check, globe, and diaphragm. The use of frictional reactive elements has greatly reduced valve noise. Research continues through use of mathematical modeling to further decrease valve noise.

Pumps - A pump accelerates a mass of fluid from a region of low pressure to higher pressure. This acceleration is accompanied by an opposing force on the housing. If the acceleration is smooth and uninterrupted, what little noise is produced is due primarily to flow interaction. An axial flow pump most closely approaches such conditions but its internal components generate noise. A centrifugal pump is also an inherently quiet design but noise is generated at blade frequencies. Piston pumps add noise because of the gears themselves. All mechanical pumps are subject to noise from leaks at some shaft seals. Noise control has been achieved by selecting the quietest usuable type pump. Research is being conducted to determine more accurately the characteristics of the pump noise and to develop quiet new components. In particular, impeller design modifications for centrifugal pumps are being studied.

Noise Criteria - Naval research is also underway to develop improved measuring techniques to simplify procedures and to permit measurement of equipment noise in any space configuration in manufacturing plants. The measurement technique will permit noise levels at the operator's position to be determined regardless of the environment and proximity of other machines.

2.1.2 DOD/U.S. Army/MERDC

The Army Mobility Equipment Research and Development Center (MERDC) at Ft. Belvoir, Va., has several noise reduction projects which are listed in Table 2.2. These are briefly described below.

Portable Equipment - A 17 cubic meter per minute (CMM) (600 CFM) portable air compressor and three mobile electric generators (1.5W, 30 KW, and 60 KW) are being addressed in current programs. The compressor project cost $98K in FY 73. The two larger generators were funded at $80K in FY 73 with a supplement of $50K in FY 74. Because the smaller generator project has just begun, the funding has not been determined. The goal for the larger portable electric generators was to obtain a reduction from the present 93-94 dBA at 7.6 meters (25 feet) to the middle of the 70-80 dBA range. So far, the program has accomplished a reduction to 76-77 dBA at 7.6 meters (25 feet). The smaller (1.5KW) generator project has already achieved a prototype with a noise level of 60-64 dBA at 3.05 meters (10 feet). It is said to be practically inaudible at 30.5 meters (100 feet).

Table 2.2 USA MERDC MACHINERY NOISE RD&D

	Investigator	FY Funding ($K) FY 73	FY 74	FY 75
Portable Equipment				
Compressor Noise Control	Martin-Marietta Laboratories and Lord Corporation	98		
Electric Generator Noise Control		80	50	
Air Conditioner Noise Control[1]	In-house		400	200[1]
Equipment Noise Survey & Evaluation[2]	In-house			
Military Standard Engines, Manifold				
Muffler[4]				
Rock Drill, Crawler Mounted				
22BM Crane-Shovel[4]				
4.536 metric ton (5 ton) crane, wheeled				
Compressor 17 cmm (600 cfm) 2/6V-71N engine[4]				
1.7 cmm (60 cfm), .46 kg/cm^2 (6.5 psi) compressor				
21.2 cmm (750 cfm) compressor				
Mixer, Rototiller[5]				
Radial arm saw[4 5]				
211 kg/cm^2 (3000 psi), .425 cmm (15 cfm) compressor[4]				
Concrete Saw				
Map Printing Van				
Hydraulic Noise[3]				
TOTALS		178	450	200[1]

[1] Funding approved for future years

[2] Nominal in-house funding, not dedicated to noise

[3] Work carried out relative to surface vehicles but applicable to machinery noise. Covered in surface vehicle report. (Ref. 9)

[4] Prior to FY 73

[5] Operator position only

Air Conditioners - A program has been initiated to reduce the noise level of military standard air conditioners below the speech interference levels of MIL-STD-1474. (Ref. 7) Work will include redesign of components, evaluation of mounting techniques, and other installation and application methods. The goal of the program is to reduce the noise levels of the units to approximately 55 dBA, 57 dB PSIL-4, or NC-60 (approximately equivalent levels).

Equipment Noise Survey and Evaluation - MERDC has also surveyed and partially evaluated the noise levels of a variety of other machinery including military standard engines, rockdrill, crane-shovel, 4.536 metric ton (5 ton) crane, compressor, rototiller mixer, radial arm saw, concrete saw, ditcher, and map printing press. The work has been performed with nominal in-house funding, not dedicated to noise. The survey was concerned with both operator noise exposure and noise levels measured at 15.2 meters (50 feet).

Hydraulic Equipment - MERDC has had two projects on hydraulic pumps and systems in vehicles. These projects are covered in the surface vehicle panel report (Ref. 9) but the hydraulic equipment is identical to that used in many industrial applications. Major efforts involved isolating mounts and covering up components, but further basic work was needed. The initial approach was to try to select a "quiet" pump, but it was determined that there were no satisfactory standards for measuring pump noise. Work was done in conjunction with Oklahoma State University (OSU) and the National Fluid Power Association (NFPA) to develop a procedure which has subsequently been submitted to the International Organization of Standardization (ISO). As the vehicle studies progressed, it became apparent that although most pumps are rated by their airborne noise levels, the real problem is the "noise" that is fluidborne and released downstream at the hoses, valves, and reservoirs. Levels reached the equivalent of over 200 dBA. It is interesting to note that in either case the noise is more adversely dependent upon the shaft speed than system pressure, but this is more true for fluidborne noise. In this study, no attempt was made to develop a "quiet" pump but rather to give an effective means to tradeoff performance parameters in order to reduce noise. Present work generally has been to study the phenomenon of noise in hydraulic systems. This will continue in the future along with the development of practical means to reduce noise.

2.1.3 DOD/U.S. Army/CERL

The U.S. Army Construction Engineering Research Laboratory (CERL) has a single project dealing with measurement methodology for construction sites. Funding was $40K in FY 74 and $45K in FY 75.

Construction Noise: Specification and Control

a. Background information and data will be compiled into a manual for a number of different task areas, which include the noise to be expected from construction sites as a function of the various phases and types of construction, known specifications and regulations dealing with construction site noise, methods to measure the noise of construction sites, background information indicating the need for attention to noise emitted from construction sites, information dealing with the means to lessen the noise impact, and information and data relating to the cost effectiveness of these noise attenuation means. Specifications will be prepared which will be appropriate for different types of construction or localities.

   Various measurement methods will be investigated for their appropriateness in testing for compliance with standards and establishing the noise from construction sites. Existing methods to attenuate noise emitted from construction sites, specifically alternate equipment, alternate methods, and physical attenuation will be reviewed.

b. New methods will be developed to mitigate the noise impact of construction sites with particular emphasis on the current and near future problems of military construction. The cost effectiveness will be determined for the various alternative means to attenuate the noise impact of construction sites.

2.2 NATIONAL BUREAU OF STANDARDS

NBS has research activities both in building acoustics and in development of measurement methodologies for sources of machinery noise. A summary of the funding for these activities is shown in Table 2.3.

Table 2.3
NBS MACHINERY NOISE RD&D
(In-house)

	FY Funding ($K)		
	73	74	75
Activity			
Building Acoustics	97	144	145
Machinery Noise Measurement Methods	41	120	120
TOTALS	138	264	265

Building Acoustics - This activity's objectives are: 1) Improve present methodologies for measuring noise isolation provided by barriers, terrain, vegetation, and building shells. 2) Provide techniques for predicting sound propagation from exterior noise sources into occupied spaces. 3) Evaluate engineering data and information to assist designers in providing protection against noise of exterior origin. 4) Improve present measurement methodologies for measuring and controlling noise generation and propagation between rooms as well as building equipment noise, in order to provide essential, technically reliable noise control measurement procedures to industry and government.

The specific approaches will be to: 1) Develop new or improved measurement methodology for assessing noise generation and propagation within rooms, buildings, and building equipment noise. 2) Characterize the force spectra of "typical" sources of impact excitation, such as footsteps and characterize the vibratory and acoustic response of structural elements for specified excitations. Combine to yield predictions of the response and radiation of floor-ceiling models for "typical" impact excitation. Subject results to experimental verification. 3) Study human response to transient intrusive noises with the objective of correlating physical measures of noise with

related subjective measures of acceptability or annoyance. 4) Develop new and earlier measurement methodologies for field measurement of airborne noise propagation between adjacent rooms and compare and extend by analysis and experiment.

Machinery Noise Measurement Methods - This activity will determine the adequacy of present measurement standards for the determination of sound power emitted by noise sources, and develop measurement methods and improvements of these standards in order to reduce measurement errors. A critical review of present American and international measurement standards is being conducted in order to assess the adequacy of these standards for the determination of sound power emitted by noise sources. The technical community and governmental regulatory agencies will be advised of the consequences of this critical review, and changes in the measurement procedures will be suggested as indicated. In order to gain direct familiarity with these procedures, they are being tried using the NBS reverberation room and anechoic chamber facilities. It is intended that by these means both industry and government will be provided a sound technical basis for the regulation and labeling of noise emissions from a variety of products.

2.3 NATIONAL SCIENCE FOUNDATION

NSF supports fourteen grants in various areas of machinery noise research. Sources addressed include heat exchangers, pipelines, industrial processes, ducts, nozzles, combustion noise, diesel engines, appliances, and machine tools. Control of the noise path is addressed in several grants on noise propagation, transmission, and absorption. Finally, NSF has funded a grant for computer prediction of noise levels in manufacturing areas. Titles and funding for each project are found in Table 2.4.

Flow-Induced Vibration and Noise in Heat Exchangers - The friction loss, performance, vortex shedding, plate vibration and noise generation in a tubular heat exchanger surface with slotted fins (such as in dry cooling towers) installed in a low turbulence, subsonic wind tunnel will be studied. The loss across the test core and the amplitudes and frequencies of the vortex shedding from perforated holes, plate vibrations and noise generated will be measured and correlated with a theoretical model as functions of the governing parameters. These results will be used to determine the mechanisms which cause flow-induced plate vibration and noise generation; the relationship between the friction coefficient and the flow-induced oscillations; the influence of perforated hole arrangements, in-line and staggered patterns; and the effects of physical parameters, such as the surface and frontal porosities and the flow length to hydraulic diameter ratio, on the flow-induced oscillations.

Table 2.4 NSF SPONSORED MACHINERY NOISE RD&D

Project Title	Recipient Institution	FY Funding ($K)[1] 73	74
Flow-Induced Vibration and Noise in Heat Exchangers	University of Michigan		65.4[2]
Cavitation Damage Scale Effects for Sudden Enlargements in Pipelines	Colorado State University	74.5[2]	-
Research Initiation - Impact Mechanics and the Generation of Impulsive Sound	Pennsylvania State University	17[3]	-
Basic and Applied Studies of Noise	Stanford University	87[3,5]	-
Attenuation of High-Intensity Sound in a Condensing Vapor	Syracuse University	0	26
Combustion Generated Noise[4]	Georgia Institute of Technology	-	-
Controlling the Noise Radiated from Diesel Engines[4]	Purdue University	-	-
Noise and Vibration from Transportation Vehicles and Other Machinery	Purdue University	-	272[6]
Acoustic Propagation in Branched Solids	University of Texas at Austin	49.5	74[2]
Sound Transmission in Buildings	Massachusetts Institute of Technology	15	
Research on Noise Propagation	Massachusetts Institute of Technology	-	152[2]
Acoustically Absorbent Materials[4]	Pennsylvania State University	-	-
Optimum Design of Partitions for Minimum Sound Transmission[4]	Carnegie Mellon University	-	-
Prediction of Noise Levels in Manufacturing Areas	Virginia Polytechnical Institute	0	39[2]
TOTALS		243.0	356.4

[1] NSF Funding cannot be predicted for FY 75
[2] Funding for 24 month period
[3] Funding for 18 month period
[4] Funding in FY 72 for 24 month period
[5] Includes some minor Surface Vehicle related work
[6] Majority of work is Surface Vehicles and funding is not included in the totals.

With these theoretical and experimental results, some guidelines will be recommended for practical design considerations to reduce both plate vibrations and noise. Important new applications will then become feasible for automotive and marine power propulsion systems, commercial and domestic air conditioning and heating systems and the dry cooling tower for electric power plants.

Cavitation Damage Scale Effects for Sudden Enlargements in Pipelines - The purpose of this research project is to determine the incipient cavitation damage index for sudden enlargements of various dimensions and the evaluation of the scale effects from the data taken. Furthermore, studies will be carried out on the vibration and noise levels for cavitation index values between the incipient and incipient damage conditions.

Research Initiation - Impact Mechanics and the Generation of Impulsive Noise - The phenomenon of high speed impact between solid bodies in a fluid medium will be examined in reference to numerous industrial machining processes which produce dangerously high levels of repetitive, impulsive noise. The investigation is three-pronged: 1) Noise tape samples obtained from numerous industrial concerns using forging, blanking, and impact extrusion processes will be examined with respect to spectral content, intensity levels, rise times, and pressure durations to classify and describe impulsive sound characteristics. 2) An impact simulation mechanism will be designed and built to evaluate the degree to which geometric and material modifications of existing impulsive-type machinery could reduce noise levels. 3) An analytical treatment will model and predict characteristics of the impact phenomenon.

Basic and Applied Studies of Noise - Specific work supported under this grant will be basic research on the mechanics of tire noise, sound generation and propagation in internal flows, and practical applications of pitch sequencing.

The sound transmission characteristics of high-speed internal flows (piping, orifices, etc.) and the sound generation characteristics of blockage elements (orifices, diffusers, etc.) will be studies using techniques extended from work on turbulent shear flows in similar devices. The initial work will consist mainly of rig design, construction, and technique development.

A study of applications of the pitch sequencing concept (piecewise frequency modulation as used in tire tread designs) will be made in a variety of systems (sawblades, blowers, etc.).

Attenuation of High-Intensity Sound in Condensing Vapor - Recent experimental evidence suggests that aerodynamic noise in ducts and nozzles is

significantly reduced in the presence of small water droplets. It is difficult to account for the observed reduction on the basis of existing theories of sound attenuation in condensing vapors. The proposed research suggests an additional mechanism for attenuation of high-intensity sound in a condensing vapor. This mechanism is enhanced heat and mass transfer between the vapor liquid phases due to acoustic streaming about the droplets at high levels. Other possible phenomena that may account for large sound reduction in duct and nozzle flows containing a condensing vapor will also be considered. It is hoped to provide both an explanation for high sound attenuation in condensing vapors and a means to predict the attenuation. Such a goal, if realized, will have important implications for the evaluation of methods to reduce internal noise in ducts, pipelines, and turbomachinery.

Combustion Generated Noise - A combined experimental-theoretical program will be undertaken to isolate the origin of combustion generated noise and to discover appropriate scaling rules associated with this noise. Primary attention will be on premixed turbulent flames, although several aspects of diffusion flame noise will also be investigated.

The data obtained on free flames will be analyzed and compared with theory. Correlations will be obtained for sound power output, directionality, and spectral content. The relation between the reaction rate fluctuations and the sound power output will be determined. An analysis will be made for the radiation of noise from a flame-containing enclosure to the surroundings. The modification to sound power output, spectral content and directionality will be compared with free flame generated noise.

Controlling the Noise Radiated from Diesel Engines - There are two main sources of noise in diesel engines: combustion noise due to burning of fuel and mechanical noise due to operation of the engine. Aspects of both sources of noise will be examined. The combustion noise will be studied by a simulation method. Here a pressure pulse will be supplied to one cylinder from a pressure source. Both cylinder pressure-time history and the pressure-time history external to the engine will be measured. From these measurements the noise attenuation of the engine will be determined at different frequencies using Fourier analysis. It is also hoped that this attenuation will be checked with the engine running and driving a dynamometer. In the combustion noise simulation study, the effects that structural changes in the engine have on noise attenuation can be examined without masking from mechanical noise. The mechanical noise will be measured by driving the engine with an electric motor. Using this method, certain aspects of the mechanical noise can be examined without masking from combustion noise.

Noise and Vibration from Transportation Vehicles and Other Machinery - To complement the ongoing research at the Ray W. Herrick Laboratories

of Purdue University, a broad range of research projects in noise control and acoustics will be undertaken. These include: enclosure design, automobile engine noise source identification and reduction; noise attenuation measurements in mufflers; tire noise generation; appliance noise reduction; machine tool noise reduction; barrier design; community noise from rapid transit vehicles; and other projects. A new addition, a semi-anechoic facility with overall dimensions 9.75 X 20.12 meters, (32 X 66 feet), will be built to accomodate many of the new projects.

Acoustics Propagation in Branched Solids - Experimental and analytical research will be performed on the propagation of sound through branched and interconnected solids. The experimental research will be performed by propagating pulses of acoustical energy at several frequencies along solid waveguides onto which branches will be attached at various angles by various means. The solid waveguides will be made long enough to be investigated and measured without the interference from reflections. As the work progresses, materials with several values of dilatational and shear sound velocities and densities will be used as branches, and several shapes, machined or formed of such materials, will be inserted as diffraction elements in the main waveguides and in the branches. As part of the work, effort will be applied to measuring acoustic beam patterns in solids in order to better define the relationship between the distribution of acoustical energy within a driven solid and the mechanical properties, shape, and size of both the driving and driven solids and the orientation of the former to the latter. Also, the experimental work will include an investigation of various acoustical resistance devices to discover which are most suitable for use as impedance matching terminations for acoustical waveguides. The analytical research will be performed using the results of the experimental work and will extend the theory of acoustic propagation in solids.

Sound Transmission in Buildings - This research is relatively broad -- it is expected to cover the more "conventional" aspects of sound transmission through walls, ceilings, floors, etc., and also sound propagation through corridors, doorways, and "open plan" landscaped areas which are more frequently being used in office buildings.

Research into noise transmission between rooms in buildings has concentrated largely on the acoustic transmission properties of walls and wall building materials. However, with the advent of open plan designs in both living and office spaces the problem of acoustical rather than structural transmission becomes important. Even in the traditional design of building interiors noise transmission from room to room through openings can be an important consideration. Recently there has been an impetus for a better theoretical understanding of transmission loss through walls. This is because of the advent of lightweight construction and emphasis on better acoustical design.

One of the major purposes of this research is to apply newly developed procedures from aerospace studies to the problems of obtaining better acoustical performance of wall structures.

A multiple purpose, semi-anechoic room will be constructed and used for the following experiments: 1) Open plan office psychoacoustical and acoustical measurements. 2) Measurements of acoustical absorption coefficient by reflection-correlation method. 3) Measurements of footfall noise on carpet-like materials.

Research on Noise Propagation - The distribution of sound within buildings and the exterior acoustical environment of buildings will be determined. In the former category, it is proposed to study sound transmission through composite structures which are of interest in newer forms of modular housing and are also used as enclosures for machines and other noise sources in industrial plants. In the latter category, it is proposed to study sound transmission in corridor-like channels which relate to the corridors in buildings and to sound transmission in city streets. An important parameter of corridor propagation is the sound absorption and scattering of the bounding surfaces at particular angles of incidence. A correlation technique for measuring these reflection coefficients will be developed. Finally, research will be performed on a "cellular" model of propagation in complex spaces that applies to sound distributions in open plan offices, certain kinds of industrial plants, and to urban noise systems.

Acoustically Absorbent Materials - The goal of this proposed study is to obtain a deeper understanding of the behavior of sound absorbing materials through a theoretical and experimental program so that optimum use can be made of these materials as duct liners to control noise from larger air moving systems. To meet this goal, a study will be undertaken of the behavior of acoustically absorbent material when subjected to high intensity noise and as a function of flow over the surface. The effectiveness of the material as a function of the angle of incidence at which the sound strikes the material will also be determined. Another important aspect of the proposed work is the determination of the behavior of high intensity complex acoustic modes in ducts in the presence of the cited conditions.

The results of this program will provide new knowledge to design acoustically absorbent materials in optimum geometric configurations for duct liners, and signficantly better acoustic and aerodynamic performance.

Optimum Design of Partitions for Minimum Sound Transmission - The aim of this program is to integrate recent advances in optimal structural

design with modern approaches to theoretical architectural acoustics. The specific objective is to develop approaches to optimal design of partitions to minimize the transmission of sound. The acoustical theory techniques considered will include variational methods as well as computer oriented techniques.

Prediction of Noise Levels in Manufacturing Areas - A computer-based acoustical model of typical industrial manufacturing facilities will be developed to enable the prediction of noise levels at specified points in manufacturing areas. The program will be written such that only a limited acoustics background will be required of a user. Basic information on physical plant arrangements and equipment installations are envisioned as input data. The computer will carry out the acoustic computations and give predicted noise levels using superposition, room acoustics, and geometric acoustics concepts. Results will be conveyed to the user in a number of different ways, depending upon the need, computer, or computer terminal capability. The reliability of the program to model industrial noise environments will be field-tested in the plants of a number of firms which have agreed to cooperate in this research effort.

2.4 DEPARTMENT OF THE INTERIOR/BUREAU OF MINES

The Bureau of Mines conducts machinery noise RD&D to support its mission of providing a healthful mine environment. It supports research on several pieces of mine machinery and is attempting to characterize the noise in mines from other machines. Table 2.5 gives titles and funding of these projects.

Alternate Conveyor Designs for Mine Machinery - The purpose of this project is to design and develop a new conveyor system which can be adapted to existing machinery to reduce the noise from the conveyor to 90 dBA. A prototype of a quieter conveyor for a specific machine used in underground coal mining will be developed.

Noise Control in Surface Mining Facilities -- Problem Definition - This project is intended to develop economical noise control of chutes, demonstrate utility, survivability, and repairability of such measures in the field and to develop screens that are quieter and no harder to maintain than existing systems. Development of the successful methods would quiet two of the principal sources of noise in surface facilities associated with coal mines.

Abatement of Noise from Pneumatic Rock Drills - This study will examine the use of ferrous and nonferrous damping alloys for reduction of noise by methods suitable for application in the mining environment and will advance toward the goal of a pneumatic percussive drill with a

Table 2.5 BUREAU OF MINES MACHINERY NOISE RD&D

Project Title	Project Number	Investigator (s)	FY Funding ($K) 73	74	75
Alternate Conveyor Designs for Mine Machinery	H0144078	Foster-Miller Assoc., Inc.	0	148.8	-
Noise Control in Surface Mining Facilities--Problem Definition	H0133027	Bolt, Beranek,& Newman, Inc.	79.4	16.7	0
Noise Control in Surface Mining Facilities--Chutes and Screens	H0144079	Bolt, Beranek,& Newman, Inc.	0	112.4	0
Abatement of Noise from Pneumatic Rock Drills	07009	In-house	90.1	0	0
Muffler for Pneumatic Drill: 1. Analysis & Design 2. Analysis of Mechanical Noise 3. Abatement of Mechanical Noise 4. Larger Class Drill	H022048	United States Steel Corp.	56.6	15.1	0
Problem of Coal Mine Noise Generation and Correction	03009	In-house	100.2	137.3	100
Noise Abatement in Mining Machinery	H0122054	Apt, Bramer, Conrad,&Assoc.Inc.	10.4	39.5	0
Noise Control of Underground Diesel-Powered Equipment--Problem Definition	H0346046	Bolt, Beranek,& Newman, Inc.	0	58.7	0
TOTALS			336.7	528.5	730 *

* Projected.

noise level no greater than 90 dBA. The principal accomplishments to date have been a prototype drill with muffler-jacket, alloy rotational chuck and constricted layer on 25 percent of the drill rod. The prototype had a noise level of 104 dBA with a reduction of about 9 percent in efficiency.

Muffler for Pneumatic Drill: 1. Analysis and Design. 2. Analysis of Mechanical Noise. 3. Abatement of Mechanical Noise. 4. Larger Class Drill - This project is intended to design and deliver a prototype muffler to attenuate the air-exhaust noise of a 34-kg.-class (75-pound-class) pneumatic stoper drill to 90 dBA with insignificant back pressure and no icing problems; develop a kinematic model simulating the moving parts of a pneumatic drill; use this model to optimize noise abatement designs of a drill and drill rod; and design and construct prototype mufflers for a large drill (7.1 cmm) (250 cfm) class. To date, the project has resulted in four prototype mufflers which were designed and fabricated for a pneumatic percussive drill of the 34-kg. (75-pound) class and reduced the exhaust noise below 90 dBA with no icing or back pressure problems.

Problems of Coal Mine Noise Generation and Correction - This project will attempt to define the noise problems in various types of mining operations; to develop and evaluate monitoring instrumentation and personal ear protective devices; and to reduce the noise levels of pneumatic drills. So far, this project has produced: a personal, pocket-size audiodosimeter that records the miner's exposure to intermittent noise levels encountered and an earmuff incorporating a special intercom system that allows the wearer to perceive low-level sounds (up to 83 dBA) at full volume but progressively attenuates louder noises to below 90 dBA. It also has demonstrated feasibility of fabricating a noise control system durable enough for the mine environment and capable of reducing the noise level of a pneumatic percussive drill from 115 to 101 dBA at the operator's position.

Noise Abatement in Mining Machinery - This project will define the noise sources from bolters, loaders, and continuous miners and will assess in-mine corrective measures to reduce operating exposure to noise levels of 90 dBA. The proposed measures will be then be experimentally evaluated for effectiveness on a loader, continuous miner, and a rotary roof bolter. The output of the project will be a report describing in detail the three machines selected, the noise sources, the corrective measures applied, and the results from testing the modified machines in a mine for one month.

Noise Control of Underground Diesel-Powered Equipment -- Problem Definition - The project's objectives are to define the magnitude of the noise problem from diesel-powered mining equipment and to evaluate

available noise control techniques for effectiveness in reducing noise levels to 90dBA. Hopefully, the project will validate a method to predict anticipated underground noise levels from sound power data obtained on the ground surface. This project is a first step toward reducing noise from diesel-powered mining equipment.

2.5 NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

The NIOSH effort in machinery noise control RD&D is intended to foster the development of improved control technology for reducing major sources of industrial noise and to formulate and promote procedures for minimizing noise problems in the work environment. This objective is in accordance with the Occupational Safety and Health Act of 1970 (Public Law 91-596) and the Federal Coal Mine Safety and Health Act of 1969 (Public Law 91-173) which charge NIOSH with undertaking research and related activities basic to assuring safe and healthful workplace conditions. In addition to assembling and preparing information on noise control techniques and materials in manuals and easy-to-use guides for coping with occupational noise problems, NIOSH also supports several grants dealing with the development and demonstration of engineering control measures for reducing major sources of machinery noise in the textiles, wood-products and metal fabricating industries. The NIOSH projects are summarized in Table 2.6.

Noise Control Research in Wood Planers - These experimental studies are aimed at reducing noise from woodworking machinery, particularly wood planers.

Coordinated Textile Industry Noise Reduction Program - This project will collect and develop information on noise control methods in the textile industry. Noise levels associated with typical operations will be identified.

Punch Press Noise Reduction - Consideration will be given to all standard noise control techniques, including reduction of noise from vibrating machine parts, gears, clutch and brake operations, air valve exhausts, and punching operations. Force reduction through tool design, use of damping material mufflers, isolation, enclosures, barriers, and absorption as well as innovative concepts will be evaluated. The results will be prepared for utilization by smaller companies which do not have extensive engineering capability.

Industrial Noise Control Manual - This activity will develop a guidebook for reducing occupational noise exposure, using case-history examples of industrial noise control efforts.

Table 2.6 SUMMARY OF NIOSH SUPPORTED MACHINERY NOISE RD&D

Project Title	Investigator (s)	Funding ($K) FY 73	FY 74	FY 75
Punch Press Noise Reduction	N.C. State University	0	53.8	
Noise Control Research in Wood Planers	N.C. State University	0	51.8	38.8
Coordinated Textile Industry Noise Reduction Program	N.C. State University	0	120	99.5
Industrial Noise Control Manual	Industrial Noise Services Inc.	16	0	0
Compendium of Noise Control Materials *	IIT Research Institute			
Impulse Noise Recording Systems **	In-house			
TOTALS		16	225.6	138.3

* Funding in FY 72

** Nominal in-house funding

Compendium of Noise Control Materials - This activity will result in a cross-referenced publication of published noise attenuation data for all known building and noise control materials.

Impulse Noise Recording System - Instrumentation was developed to facilitate recording of impulse waveforms in industrial environments, using digital recording techniques.

2.6 ENVIRONMENTAL PROTECTION AGENCY

EPA has sponsored several studies to support regulatory needs in machinery noise. The studies have been for defining measurement methodologies, available technology, and cost for compliance specifically for various pieces of construction equipment. Similar studies on pneumatic and hydraulic drills and pavement breakers are expected to begin in FY 75. Table 2.7 lists the studies and funding levels.

Table 2.7 EPA MACHINERY NOISE RD&D

Project Description	Investigator	Funding ($K) FY 73	FY 74	FY 75
Portable Air Compressor Noise Technology and Cost	Bolt, Beranek & Newman Inc.	0	91	0
Construction Noise Study	Bolt, Beranek, & Newman Inc.	0	25	0
Economic Impact of Portable Air-Compressor Noise Emission Standards	A. T. Kearney Inc.	0	50	0
Development of Noise Measurement Methodology for Portable Air Compressors	N.B.S.	60	64	0
Pneumatic and Hydraulic Drills and Pavement Breakers - Technology, Costs, and Economic Impact		0	0	100
TOTALS		60	230	100

Portable Air Compressor Noise Technology and Costs - This study examined the technology currently available for portable air compressors and the attendant costs to achieve various study levels.

Construction Noise Study - This study examined a series of regulatory approaches aimed at quieting construction sites to various study levels. The study considered resource costs to the nation as well as the anticipated effectiveness of the approach.

Development of Noise Measurement Methodology for Portable Air Compressors- This study examined the correlation between far field sound measurements and those taken in the near field. It also provides a recommended sound power measurement procedure for determining the near field noise levels of portable air compressors.

Pneumatic and Hydraulic Drills and Pavement Breakers-Technology, Costs, and Economic Impact - This study will examine the technology available, attendant costs for reducing the noise output to various noise levels and the corresponding economic impact of regulating these products to those levels.

2.7 CONSUMER PRODUCT SAFETY COMMISSION

CPSC has the primary responsibility for establishing mandatory product safety standards, where appropriate, to reduce the unreasonable risk of injury to consumers from consumer products. The CPSC in FY 74 supported research to develop a consistent set of product noise regulations, a test protocol for lawn mowers, and test methods for toys. A summary of the project funding is shown in Table 2.8.

Table 2.8 CPSC MACHINERY NOISE RD&D

Project Title	FY 74 Funding ($K) *
Developing a Consistent Set of Product Noise Regulations	20
Test Protocol for Lawnmower Noise	15
Noise Measurement Techniques for Toys	35
TOTAL	70

* Projects supported only in FY 74.

Developing a Consistent Set of Product Noise Regulations - This project will assess current knowledge and recommend additional research to determine patterns of noise exposure due to usage of select products, define practical sound level measurement procedures, define hearing loss from product use, and define potential for product noise to mask auditory warnings.

Test Protocol for Lawnmower Noise - The hazard caused by noise from lawnmowers will be investigated. A maximum sound level will be suggested with methods for measurement at the operator's ear position.

Noise Measurement Techniques for Toys - This project will identify noise-producing toys which are potentially hazardous to children's hearing and/or safety, develop generic test methods by which the noise exposure due to such toys can be determined and acquire data on selected toys. Simple screening procedures will be developed for rapid determination as to whether toys require detailed laboratory testing.

2.8 DEPARTMENT OF AGRICULTURE

USDA is funding a research project on agricultural processes noise. It began in FY 74 and is currently in a problem definition phase. The work is being conducted at Richard B. Russell Agricultural Research Center, ARS, USDA, P.O. Box 5677, Athens, Georgia 30604. The funding is $20,000 in FY 74 and $92,470 in FY 75.

Abatement and Control of Noise Associated with Agricultural Processes- The objectives are to determine the degree of noise pollution occurring in various types of agricultural processing plants under normal operating conditions, determine primary vibration sources contributing to high power level noise within processing plants, and develop and implement methods and equipment to abate and control noise levels.

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3.0 ANALYSIS OF FEDERAL MACHINERY NOISE RD&D

The current Federal research, development and demonstration activities address a number of specific sources of machinery noise, undertake work in building and structural transmission of noise, and work towards better definition of the machinery noise problem through measurements and development of more accurate and standardized measurement methodology. The general funding in these areas is presented in Table 3.1. It can be noted that the majority of funds are spent on control technology. This observation is further supported by the Navy's million dollar a year program, most of which goes for source control technology. In contrast, the funds in the building and structural category are small. It also appears that the funds for machinery noise RD&D peaked in FY 1974. This apparent peaking may not be actual, however, due to the uncertainty of the FY 1975 data.

Agencies' current involvements in the three categories of machinery noise RD&D activities are shown in Table 3.2. USDA and CPSC currently are involved only in measurement or measurement methodology. NSF, DOD and NIOSH are supporting research in all three areas, while BuMines, NBS, and EPA are involved in two categories. The following discussions summarize the current effort of the Federal Government in addressing these categories of machinery noise.

3.1 SOURCE NOISE CONTROL TECHNOLOGY

Five agencies have RD&D activities addressing noise control technology for machines. Table 3.3 summarizes the specific sources addressed by each agency and the funding data (if available). NIOSH is currently funding noise control work on machines that have a significant impact on the occupational environment. The machines presently studied are punch presses, wood planers, and various textile industry machines. NIOSH has also funded the development of an industrial noise control manual. Bureau of Mines supports work on various machines that affect the mine work place. Sources addressed include conveyors, chutes and screens used in coal cleaning, pneumatic drills, diesel powered equipment, continuous miners, loading machines, and roof bolters. The Navy supports work on shipboard machinery because of the need for quiet ships. Although specific activities cannot be reported for security reasons, in general the sources addressed are diesel engines, hydraulic systems, pneumatic machinery, rotating electrical machinery, electronic equipment, gas turbines, compressors, fans, gear valves, and pumps.

Table 3.1 SUMMARY BY AREA OF MACHINERY NOISE RD&D

RD&D Area	Funding (thousand dollars) FY 73	FY 74	FY 75
Source Noise Control Technology	529	1,307	1,168
Building and Structural Noise Transmission and Control	162	370	145
Measurements and Measurement Methodologies	280	507	257
TOTALS	971	2,184	1,570

Table 3.2 CURRENT AGENCY INVOLVEMENT IN AREAS OF MACHINERY NOISE RD&D

Research Area	BUMines	NIOSH	NSF	DOD	NBS	EPA	CPSC	USDA
Source Noise Control Technology	X	X	X	X		X		
Building and Structural Noise Transmission and Control		X	X	X	X			
Measurements and Measurement Methodologies	X	X	X	X	X	X	X	X

Table 3.3 SOURCE NOISE CONTROL TECHNOLOGY

Agency	Source	Funding (thousand dollars) FY 73	FY 74	FY 75
NIOSH	Punch Press	0	54	
	Wood Planers	0	52	38
	Textile Industry General	0	120	100
	Industrial Noise Control Manual	16	0	0
	TOTAL	16	226	138
BuMines	Mining Machinery Conveyors	0	148.8	0
	Surface Facilities Chutes and Screens	0	112.4	0
	Pneumatic Drills	146.7	15.1	0
	Underground Diesel-Powered Equipment	0	58.7	0
	Continuous Miner, Loading Machine, Rotary Roof Bolter	10.4	39.5	0
	TOTAL	157.1	374.5	730 [1]
NSF	Heat Exchangers	0	65 [2]	-
	Pipelines	74.5 [2]		
	Impact Noise-Industrial Machinery Processes	17 [3]		
	Basic & Applied Studies of Noise (Tires, Internal Flows, Pitch Sequencing)	87 [3,5]		
	Ducts and Nozzles	0	26	
	Combustion Noise [4]			
	Diesel Engines [4]		272 [6]	
	Appliances, Machine tools, Barrier design [6]			
	TOTAL	178.5	91	--

Table 3.3 SOURCE NOISE CONTROL TECHNOLOGY (continued)

Agency	Source	Funding (thousand dollars) FY 73	FY 74	FY 75
USN	Diesel Engines			
	Hydraulic Systems			
	Pneumatic Machinery			
	Rotating Electrical Machinery			
	Electronic Equipment			
	Gas Turbines			
	Compressors			
	Fans			
	Gears			
	Valves			
	Pumps			
U.S. Army	Air Conditioners	0	400	200 [1]
	17cmm (600 CFM) Air Compressor	98	0	0
	Electric Generators	80	50	--
	Various other military equipment [7]			
	Hydraulic Equipment [8]			
	TOTALS	178	450	200

Table 3.3 SOURCE NOISE CONTROL TECHNOLOGY (concluded)

Agency	Source	Funding (thousand dollars) FY 73	FY 74	FY 75
EPA	Construction Noise	0	25	0
	Portable Air Compressors	0	141	0
	Pneumatic and Hydraulic Equipment	0	0	100
	TOTAL	0	166	100
	GRAND TOTALS	529.6	1,307.5	1,168

[1] Projected

[2] Funding for two year period

[3] Funding for 18 month period

[4] Funding in FY 72 for 24 month period

[5] Includes some minor Surface Vehicle related work

[6] Majority of work is Surface Vehicle and funding is included in that report. (Ref. 9)

[7] Normal in-house funding, not dedicated to noise

[8] Work covered in Surface Vehicles but directly applicable to machinery noise. Covered in surface vehicle report. (Ref. 9)

The Army has several projects which address an air compressor, three portable electric generators, air conditioners, and various other pieces of military equipment (see Table 2.2). EPA in its effort to regulate major sources of noise has developed information on available technology and cost of compliance for portable air compressors. Similar efforts on pneumatic and hydraulic equipment are projected. NSF supports research in a variety of areas. Current work in machinery noise will have application to several sources: heat exchangers, pipelines, ducts and nozzles, industrial machining processes, diesel engines, combustion sources, and appliances.

3.2 BUILDING AND STRUCTURAL NOISE TRANSMISSION AND CONTROL

Four agencies are currently involved in different kinds of activities in this area. The various projects and funding are detailed in Table 3.4. NBS has had a program for many years in building acoustics. The thrust of the current activity is to improve both measurements and design guidelines for noise control in buildings. The Navy effort is directed toward the need for quiet ships. The Navy source noise control activity is supplemented by use of structural damping, resilient mounts, and acoustical transmission loss and absorptive materials. NSF supports several research projects in this category to extend the theory of propagation of sound. These include studies of airborne and structural noise propagation in buildings and corridors, behavior of acoustically absorbent materials, design of partitions, and transmission through branched solids. NIOSH has supported a project to compile information on the acoustic and other properties of building materials and acoustical absorption materials.

Table 3.4 BUILDING & STRUCTURAL NOISE TRANSMISSION & CONTROL

Agency	Description	Funding (thousand dollars) FY 73	FY 74	FY 75
DOC/NBS	Building Acoustics Program	97	144	145
USN	Radiated and Platform Noise Sound Path Isolators			
NSF	Acoustic Propagation in Branched Solids	50	74 [1]	
	Sound Transmission in Buildings	15	0	
	Research on Noise Propagation	0	152 [1]	0
	Acoustically Absorbent Materials [2]			
	Optimimum Design of Partitions for Minimum Sound Transmission			
NIOSH	Compendium of Noise Control Materials [3]			
	TOTALS	162	370	145

[1] Funding for two year period

[2] Funding in FY 72 for two year period

[3] Funding in FY 72

3.3 MEASUREMENTS AND MEASUREMENT METHODOLOGIES

All eight agencies which fund machinery noise research have activities either to define the problems in machinery noise or to develop or improve measurement techniques for assessing the noise. NSF has funded the development of a computer-based acoustical model of typical industrial manufacturing facilities which will enable the prediction of noise levels at specified points in manufacturing areas by users with limited acoustics backgrounds. Bureau of Mines has efforts in characterizing noise and identifying problems in both underground and surface mining facilities. NBS is developing and improving methodologies for measuring sound power. EPA has supported efforts to develop measurement methodologies for various noise sources, specifically air compressors. Similarly, CPSC is supporting the development of consistent measurement methodologies for consumer products in general and specifically, lawnmowers and toys. USDA is beginning a noise control RD&D program which currently involves measurement and problem definition. The Navy is developing improved techniques for measuring equipment noise at operators' positions. The U. S. Army is working on measurement and control of construction site noise. NIOSH is developing a system for recording impulse noise. The Federal activities and projects in this category of machinery RD&D are listed in Table 3.5.

Table 3.5 MACHINERY NOISE MEASUREMENTS AND MEASUREMENT METHODOLOGIES

Agency	Project Title	Funding (Thousand dollars) FY 73	FY 74	FY 75
NSF	Prediction of Noise Levels in Manufacturing Areas	0	39	0
BUMines	Definition and Correction of Noise in Coal Mines	100	137	0
	Noise Control in Surface Mining Facilities-Problem Definition	79	17	0
EPA	Development of Noise Measurement Methodologies for Portable Air Compressors	60	64	0
NBS	Assessment of Measurement Standards for Determination of Sound Power	41	120	120
CPSC	Developing a Consistent Set of Product Noise Regulations	0	20	0
	Noise Measurement Techniques for Toys	0	35	0
	Test Protocol for Lawnmower Noise	0	15	0
USDA	Abatement and Control of Noise Associated with Agricultural Processes	0	20	92
NIOSH	Impulse Noise Recording System *			
USN	Noise Criteria			

Table 3.5 MACHINERY NOISE MEASUREMENTS AND MEASUREMENT METHODOLOGIES (continued)

Agency	Project Title	Funding (thousands dollars) FY 73	FY 74	FY 75
USA	Construction Equipment: Specification and Control		40	45
	TOTALS	280	507	257

* Nominal In-House Funding

4.0 SUMMARY AND CONCLUSIONS

There are literally countless sources of machinery noise. Machinery noise occurs in the home, hospitals, offices, and the community. Generally, however, exposure to machinery noise in the occupational environment is the most severe. Machinery noise, along with noise from other sources, may produce hearing loss, cause annoyance, affect job performance, and interfere with warning signals. Other deleterious effects may also occur, but hearing loss is generally considered the most severe. Estimates for reducing industrial noise to levels of marginal protection against hearing loss run into billions of dollars. (Ref. 5)

To get a preliminary indication of the private sector efforts in industrial machinery noise RD&D, a number of trade associations were contacted and a literature search was conducted. Conclusions were that trade associations were not a good source of machinery noise reduction technology, and that most industries have little or no on-going machinery noise control RD&D whose results will be generally available to the public.

The Federal effort on machinery noise RD&D is being conducted by eight agencies: DOD, DOC/NBS, NSF, DOI/BuMines, NIOSH, EPA, CPSC, and USDA. The Federal effort has ranged from two to three million dollars over the FY 1973 to 1975 time period and appeared to peak in FY 1974. About a million of this was allocated by the Navy to quiet ships. Much of that work is classified and is not currently available to the public.

Noise control for sources is being addressed in the mine environment, the industrial environment, the military environment and others. Some research also is directed toward building and structural noise transmission and control, and other work is going on to characterize noise environments and sources.

Although an in-depth analysis has not been done, a significant part of these Federal expenditures is directed toward establishing applications of currently available technology for future use. While the Federal Government has machinery noise RD&D activities there is not a national policy toward Federal involvement in machinery noise RD&D. Consequently, each agency conducts research to support its own mission.

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8. Military Specification 8806, "General Specification for Sound Pressure Levels in Aircraft." September 21, 1970.

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6.0 APPENDICES

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APPENDIX A

GLOSSARY OF AGENCY ACRONYMS

Symbols	Agencies
CPSC	Consumer Product Safety Commission
DOC	Department of Commerce
DOC (NBS)	National Bureau of Standards
DOD	Department of Defense
DOD/USN	Department of the Navy
DOD/USA	Department of the Army
DOI	Department of the Interior
DOI/BUMines	Bureau of Mines
DOL	Department of Labor
DOT	Department of Transportation
EPA	Environmental Protection Agency
HEW	Department of Health, Education and Welfare
HEW (NIEHS)	National Institute of Environmental Health Sciences
HEW (NINDS)	National Institute of Neurological Diseases and Stroke
HEW (NIOSH)	National Institute for Occupational Safety and Health
HUD	Department of Housing and Urban Development
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
USDA	Department of Agriculture

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APPENDIX B

FEDERAL MACHINERY NOISE RESEARCH PANEL

Mr. Stephen R. Cordle, Chairman — 202/755-0448
Noise Technology Staff (RD-681)
Office of Research and Development
Environmental Protection Agency
Washington, D. C. 20460

Captain Lester H. Beck, USN — 202/692-0872
Naval Sea Systems Command (037)
Department of the Navy
Washington, D. C. 20362

Mr. Curtis Holmer — 301/921-3381
Applied Acoustics Section
National Bureau of Standards
Room A149 Sound Building
Washington, D. C. 20234

Mr. Paul Hopler, Chief — 703/664-6713 -1836
Systems and Components Branch
U. S. Army Mobility Equipment Research
And Development Center (MERDC)
Fort Belvoir, Virginia 22060
Attention: AMXFB-HM

Dr. Morris Ojalvo — 202/632-5787
Division of Engineering
National Science Foundation
1800 G Street, N. W., Room 340
Washington, D. C. 20550

Mr. Milford Skow — 202/634-1240
Department of the Interior
Bureau of Mines
Room 9035 Columbia Plaza
Washington, D. C. 20240

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Dr. Floyd A. Van Atta — 202/961-5005
Occupational Safety and Health Administration
U. S. Department of Labor
Washington, D. C. 20210

Mr. Robert Willson — 513/684-3416
Physical Agents Branch
National Institute for Occupational Safety and Health
1014 Broadway
Cincinnati, Ohio 45202

Mr. Eugene Wyszpolski — 703/557-8292
Office of Noise Control Programs (AW-571)
Environmental Protection Agency
Crystal Mall Building 2
1921 Jefferson Davis Highway
Arlington, Virginia 20460

APPENDIX C
NOISE ABATEMENT RESEARCH BY TRADE ASSOCIATIONS

Trade associations were contacted to:

- Indicate the level of active interest by trade associations in noise abatement research.
- Indicate the type of noise abatement research being conducted by trade associations.
- Ascertain the availability of the results of the research.

Accordingly, a list of 58 trade associations, distributed over 20 industries, was compiled from Reference 2. "Small" associations, with annual budgets of less than $250,000, were not included. Telephone contacts were made to identify the availability of published results of noise research. These results are compiled in Table C-1. Some of the comments are summarized below.

- Thirty-six of the associations have not done and do not plan to do noise research.
- The research activities of 16 of the remaining 22 associations have been principally noise surveys of machinery.
- Only six of the remaining 22 associations indicated activities in noise reduction. Research included
  - Burner noise reduction by American Gas Association
  - Quiet room application by American Newspaper Publishers Association
  - Appliance quieting by Association of Home Appliance Manufacturers
  - Forging noise reduction by Forging Industry Assn.
  - Vehicle noise reduction by Motor Vehicle Mfr. Assn.
  - Machinery noise reduction by Western Wood Products Assn.
- Four of the six associations indicated that noise research results are considered proprietary and expressed concern about releasing the information to a Government agency.
- The American Trucking Association data is primarily a survey of truck noise levels. Similar, but more extensive, information is available from the Motor Vehicle Manufacturers Association.

Table C-1 SUMMARY OF INDUSTRY/ASSOCATIONS/NOISE RESEARCH ACTIVITY SURVEY

SIC Code	Industry/Associations	Research Activity	Publications Available
16	CONSTRUCTION		
	• Associated Equipment Distributors 615 West 22nd Street Oak Brook, Illinois 60521 (312)654-0650	None	None
	• Associated General Contractors of America 1957 East Street, N. W. Washington, D. C. 20006 (202)393-2040	Research Conducted through State Chapters	None
	• Construction Specifications Inst. 1717 Massachusetts Avenue. N.W. Washington, D. C. 20036 (202)833-2160	None	None
	• Construction Industry Manufacturers Associations Suite 1700, Marine Plaza 111 East Wisconsin Avenue Milwaukee, Wisconsin 53202 (414)272-0943	Conducted a Joint Program with Farm and Industrial Equipment Institute	TR-SAE-R4 A Study of Noise Induced Hearing Damage for Operators of Farm and Construction Equipment, 1969.

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATION/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publications Available
20	FOOD AND KINDRED PRODUCTS		
	• Can Manufacturers Institute 1625 Massachusetts, N. W. Washington, D. C. 20036 (202)232-4677	Plan to start project on in-plant noise reduction in the near future.	None
	• National Canners Association 1133 20th Street, N. W. Washington, D. C. 20036 (202)311-5900	None	None
	• Packaging Machinery Manufacturers Association 2000 K Street, N. W. Washington, D. C. 20006 (202)331-8181	None	None
21	TOBACCO MANUFACTURERS		
	• Tobacco Institute, Inc. 1776 K Street, N. W. Washington, D. C. 20006 (202)296-8434	None	None
22	TEXTILE MILL PRODUCTS		
	• American Textile Manufacturers Institute, Inc. 1501 Johnston Building Charlotte, N. C. 28281 (704)334-4734	Survey of Equipment Noise Levels	None, data will be used for OSHA Hearings

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATION/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publication Available
22 (continued)			
	• Carpet and Rug Institute 310 Holiday Drive, Box 2048 Dalton, Georgia 30720 (404)278-3176	Survey of Equipment Noise	Report Available
23	APPAREL AND RELATED PRODUCTS		
	• American Apparel Manufacturers Association 1611 North Kent Street Arlington, Virginia 22209 (703)524-1864	None	None
	• American Footwear Industries Assc. 1611 North Kent Street Arlington, Virgina 22209 (703)522-8070	None	None
24	LUMBER AND WOOD PRODUCTS		
	• American Forest Institute 1619 Massachusetts Avenue Washington, D. C. 20036 (202)667-7807	None	None
	• American Plywood Association 119 A Street Tacoma, Washington 98401 (206)272-2233	None	None

TABLE C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publications Available
24 (continued)			
	• National Forest Products Assoc. 1619 Massachusetts Avenue, N.W. Washington, D. C. 20036 (202)332-1050	None	None
	• Western Wood Products Assoc. 1500 Yeon Building Portland, Oregon 97204 (503)224-3930	Program on Machinery Noise	None, Reports not yet Published (1976)
	• National Hardware Lumber Assoc. 59 East Van Buren Chicago, Illinois 60605 (312)427-2811	None	None
25	FURNITURE AND FIXTURES		
	• National Housewares Manufacturers Association 1130 Merchandise Mart Chicago, Illinois 60654 (312)644-3333	None	None
26	PAPER AND ALLIED PRODUCTS		
	• American Paper Institute 260 Madison Avenue New York, New York 10016 (212)883-8000	None	None

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publications Available
26 (continued)			
	• Fiber Box Association 224 No. Michigan Avenue Chicago, Illinois 60604 (312)663-0250	Conducted Noise Survey	None
27	PRINTING, PUBLISHING AND ALLIED PRODUCTS		
	• American Newspapers Publishers Association Post Office Box 598 Easton, Pennsylvania 18042 (215)253-6155	Survey of Machine Noise and Potential Treatment	No, information is considered proprietory
	• Printing Industries of America, Inc. 1730 North Lynn Street Arlington, Virginia 22209 (703)527-6000	None	None
28	CHEMICAL AND ALLIED PRODUCTS		
	• Chemical Specialties Manufacturers Association, Inc. 1001 Connecticut Avenue, N. W. Washington, D.C. 20036 (202)872-8100	None	None
	• Oil, Chemical and Atomic Workers Union International 1636 Champa Street Denver, Colorado 80201 (303)266-0811	Survey of Machinery Noise and Hearing Damage	No, considered proprietary

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publication Available
29	PETROLEUM AND COAL PRODUCTS		
	• American Gas Association 1515 Wilson Boulevard Arlington, Virginia 22209 (703)524-2000	Program to Reduce Burner Noise	No, program Just Started
	• American Petroleum Institute 1801 K Street, N. W. Washington, D. C. 20006 (202)833-5600	None	None
	• Bituminous Coal Research, Inc. 350 Hochberg Road Monroeville, Pennsylvania 15146 (412)327-1600	None	None
30	RUBBER AND MISCELLANEOUS PLASTIC PRODUCTS		
	• Rubber Manufacturers Association 1901 Pennsylvania Avenue Washington, D. C. 20006 (202)785-2602	None	None
31	LEATHER AND LEATHER GOODS		
	• No Associations Identified		

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publication Available
32	STONE, CLAY AND GLASS PRODUCTS		
	• National Concrete Masonry Association 1800 N. Kent Street Arlington, Virginia 22209 (703)524-0813	Machinery Noise Data	If cleared for release by association
	• Glass Container Manufacturers Institute 1800 K Street, N. W. Washington, D. C. 20006 (202)872-1280	None	None
	• Portland Cement Association Old Orchard Road Skokie, Illinois 60076 (312)966-6200	Noise Surveys for Member Companies	Reports considered proprietary
33	PRIMARY METAL INDUSTRIES		
	• Aluminum Association 750 Third Avenue New York, New York 10017 (212)972-1800	None	None
	• American Iron and Steel Institute 1000 16th Street, N. W. Washington, D. C. 20036 (202)223-9040	Survey of Noise	No survey, just beginning

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publication Available
33 (continued)			
	• American Foundrymen's Society Golf and Wolf Roads DesPlaines, Illinois 60016 (312)824-0181	Participating on Hearing Damage Survey	None
	• Forging Industry Association 1211 Illuminating Building 55 Public Square Cleveland, Ohio 44113 (216)781-6260	Program on Machinery Noise Reduction	Yes - At $50. per copy. Six (6) volumes ready and six (6) not ready. No reproduction rights.
	• Gray and Ductile Iron Founders Society Cast Metals Federation Building Rocky River, Ohio 44116 (216)333-9600	Survey of Machinery Noise	No, just started
	• Steel Founders Society of America Cast Metals Federation Building Rocky River, Ohio 44116 (216)333-9600	None	None
34	FABRICATED METAL PRODUCTS		
	• Air Conditioning and Refrigeration Institute 1815 North Fort Myer Drive Arlington, Virginia 22209 (703)524-8800	None	None

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publication Available
34 (continued)			
	• American Automobile Association 1712 G Street, N. W. Washington, D. C. 20006 (202)222-6000	None	None
	• Association of Home Appliance Manufacturers 20 North Wacker Drive Chicago, Illinois 60606 (312)236-2921	Equipment Noise Survey	None
	• Farm and Industrial Equipment Institute 410 North Michigan Avenue Chicago, Illinois 60611 (312)321-1470	Survey of Hearing Damage for Operators	Yes, See CIMA (SIC 16)
	• Industrial Research Institute 100 Park Avenue New York, New York 10017 (212)683-7626	None	None
	• International Snowmobile Association 5205 Leesburg Pike Falls Church, Virginia 22041 (703)379-9100	None	None

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Associations	Research Activity	Publication Available
34 (continued)			
	• National Association of Engine and Boat Manufacturers, Inc. 537 Steamboat Road Greenwich, Connecticut 06830 (203)661-4800	None	None
	• National Association of Manufacturers 1776 F Street, N. W. Washington, D. C. 20006 (202)331-3700	None	None
35	MACHINERY EXCEPT ELECTRICAL		
	• Machinery and Allied Products Institute 1200 18th Street, N. W. Washington, D. C. 20036 (202)331-8430	None	None
	• National Machine Tool Builders Association 7901 Westpark Drive McLean, Virginia 22101 (703)893-2900	None	None
	• National Tool, Die and Precision Machining Association 9300 Livingston Road Oxon Hill, Maryland 20022 (301)248-6200	Noise Survey	Yes

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

SIC Code	Industry/Association	Research Activity	Publication Available
35	(continued)		
	• National Screw Machine Products Association 2860 East 120th Street Cleveland, Ohio 44120 (216)751-0909	Unknown	Unknown
36	ELECTRICAL AND ELECTRONIC MACHINERY		
	• Electronic Industries Association 2001 Eye Street, N. W. Washington, D. C. 20006 (202)659-2200	None	None
	• National Electrical Manufacturers Association 155 East 44th Street New York, New York 10017 (212)682-1500	None	None
37	TRANSPORTATION EQUIPMENT		
	• American Trucking Association 1616 P Street, N. W. Washington, D. C. 20036 (202)797-4000	Truck Noise Research	Yes
	• Association of American Railroads 1920 L Street, N. W. Washington, D. C. 20036 (202)293-4000	Railroad Noise Survey	Yes

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (concluded)

SIC Code	Industry/Association	Research Activity	Publication Available
37 (continued)			
	• Transportation Association of America 1101 17th Street, N. W. Washington, D. C. 20036 (202)296-2470	None	None
	• Motor Vehicle Manufacturers Association 320 New Center Building Detroit, Michigan 48202 (313)872-4311	Survey of Motor Vehicle Noise	Yes
49	UTILITIES		
	• American Public Power Association 2600 Virginia Avenue, N. W. Washington, D. C. 20037 (202)333-9200	None	None
	• Edison Electric Institute 90 Park Avenue New York, New York 10016 (212)986-4100	None	None
	• National Association of Electric Companies 1140 Connecticut Avenue, N.W. Washington, D. C. 20036 (202)223-3460	None	None

APPENDIX D

MACHINERY NOISE LITERATURE SEARCH SUMMARY

Abstracts from "Engineering Abstracts" and "Pollution Abstracts" covering the period of 1971-1974 relating to machinery noise were reviewed and their areas of activity distributed over the 20 industries shown in Table E-1. Abstracts which indicate apparent application to several industries were distributed into a "mixed category." A summary of the publication distribution is given in Table D-1 and the distribution of the publications over the 21 categories is presented in Table D-2. Briefly, the following comments are given:

- Three hundred twenty-one publications are identified as pertinent to machinery noise research; 161 primarily single industry oriented and 160 are in the mixed category. The majority (223) are U.S. publications. Ninety-eight foreign publications from 19 countries are identified.

- United States publications are distributed into 13 of the 20 industrial categories. No publications were identified in:

  - Tobacco manufacturing
  - Apparel manufacturing
  - Furniture and fixtures
  - Printing and publishing
  - Leather and leather goods
  - Electrical machinery
  - Transportation equipment

- The industry with the most publications is chemical and allied products with 42 publications. Petroleum and coal products has 26 publications, utilities has 18 and construction 18. Of the 11 publications in primary metals, only two are from the U.S.

- Foreign publications are primarily from Germany (28) and England (23). Both of these countries' publications are broadly scattered throughout the categories but pockets of concentration appear in primary metals and fabricated metal products industries and in the mixed category.

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- The review of the abstracts resulted in virtually no quantitative technical information which could be used in either assessing machine noise levels, noise reduction techniques, or the effectiveness of the application of technology. The reports must be gathered and reviewed before any assessment of this type can be made.

- Generic noise problems seem to be treated by several industries. For instance:

  - Valve Noise - Reduction activity is evident in the utilities, chemical and allied products and in the mixed category.

  - Pump Noise is treated by chemical and allied products and in the mixed category.

  - Piping System Noise reduction techniques are used by utilities, chemical and allied products, petroleum and coal products and in the mixed category.

  - Combustion Noise has literature in construction, paper and allied products, chemical and allied products and in the mixed category.

  For the generic noise problems, it would appear that transfer of technology could be effective and research activities could be defined which have relatively broad applicability to several industries.

Table D-1

SUMMARY OF PUBLICATION DISTRIBUTION

321	Publications on Machinery Noise.
161	Publications which are primarily single industry oriented.
160	Publications in mixed category applicable to several industries.
223	U.S. publications broadly scattered except weak in primary metals.
28	German publications broadly scattered throughout.
23	English publications broadly scattered throughout.
6	Russian publications in utility and machine noise, noise measurement, combustion noise, health effects and standards.
7	Japanese publications on fans, turbines, gears, grills and analytical techniques.
6	Swedish publications in construction, primary metals and fabricated metal products.
5	French publications in construction, industrial noise sources, noise measurement and circulation pumps.
5	Polish publications on analysis techniques, pumps and gear noise.
3	Canadian publications on refinery noise and plant noise standards.
3	Netherlands publications on refinery and power plant noise.
2	Australian publications on valve and fan noise.
2	Indian publications on industrial noise sources.
1	Austrian publication on noise standards.

Table D-1 SUMMARY OF PUBLICATION DISTRIBUTION (Continued)

1	Belgian publication on plant noise control.
1	Hungarian publication on pump noise.
1	Iranian publication on oil cushions.
1	Norwegian publication on construction equipment.
1	Swiss publication on heat exchanger noise.
1	Tasmanian publication on water turbines.
1	Yugoslavian publication on milling and grinding.

Table D-2

MACHINERY NOISE PUBLICATION DISTRIBUTION

SIC/ Industry	Number of Publications	Area of Publications
16 Construction Equipment	18	• Construction site noise (5-U.S.) • Pneumatic rock drill (3 - 2-U.S., 1-Norway) • Pile drivers (2 - 1-Germany, 1 - Sweden) • General discourse (1 - U.S.) • Construction equipment in general (2 - U.S.) • Cooling systems (2 - 1-France, 1 - England) • Compressors (1 -U.S.) • Pneumatic equipment (2 -1-England, 1 -U.S.)
20 Food and Kindred Products	6	• Agricultural machinery(3- U.S.) • Bottle cap plant noise (1 -U.S.) • Brewery noise (1 -U.S.) • Agricultural noise (1 -U.S.)
21 Tobacco Manufacturers	None	
22 Textile Mill Products	5	• Rotating textile spindles (1 -U.S.) • Textile machinery noise (1 -U.S.) • Textile manufacturers noise sources (1 -U.S.) • Guidelines for noise control (2 -U.S.)

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

SIC/ Industry	Number of Publications	Area of Publications
23 Apparel	None	
24 Lumber and Wood Products	3	• Saws (chain) (1 -U.S.) • Planer (2 -U.S.)
25 Furniture and Fixtures	None	
26 Paper and Allied Products	6	• Medical aspects of noise (1 -U.S.) • Stock preparation machinery (1 -U.S.) • Compressors (1 -U.S.) • Gears (3 -U.S.)
27 Printing, Publishing	None	

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

SIC/ Industry	Number of Publications	Areas of Publication
28 Chemical and Allied Products	42	• Valve noise (20 -17 -U.S., 2 - Germany, 1 - Australia) • Piping noise (3 - U.S.) • Combustion noise (2 -U.S.) • Centrifugal compressor (1 -U.S.) • Pumps (3 -2 -U.S., 1 -England) • Heat exchangers (1 -Switzerland) • Exhaust vent (1 -U.S.) • Acoustic insulation (1 -U.S.) • Process noise (10 -U.S.)
29 Petroleum and Coal Products	26	• Process machinery noise (2 -U.S.) • Fan noise (2 - 1 -U.S., 1 -Australia) • Furnace and heater noise (2 -U.S.) • Steam pipeline noise (1 -U.S.) • Stack noise (1 -U.S.) • Flare noise (1 -U.S.) • Refinery noise (10 -7 -U.S., 1 -Netherlands, 1 -Canada, 1 -England) • Rock noise location (1 -U.S.) • Noise in coal preparation plants (2 -U.S.) • Noise in underground operations (3 -2 -U.S., 1 -England) • Coal car unloading (1 -U.S.)
30 Rubber and Plastic Products	6	• Plant noise sources (2 -U.S.) • Processing plant noise (1 -U.S.) • Materials handling (1 -U.S.) • Combustion (1 -England) • Health aspects (1 -U.S.S.R.)

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

SIC/ Industry	Number of Publications	Areas of Publication
31 Leather and Leather Goods	None	
32 Stone, Clay and Glass Products	5	• Ball-mill noise (1 -U.S.) • Cement plant noise (1 -Germany) • Quarrying noise (3 -U.S.)
33 Primary Metals	11	• Electric-arc steelplant (1 -England) • Steel plant noise (1 -Germany) • Forging (3 -1 -U.S., 1 -Germany, 1-England) • Air conditioning (1 -Germany) • Foundry noise sources (5 -2 -Sweden, 1 -Germany, 1 -England, 1 -U.S.)
34 Fabricated Metal Products	12	• Impact machines (2 -U.S.) • Metal forming (1 -Germany) • Riveting machines (2 -U.S.) • Cable making machines (2 -Germany) • Punch presses (5 -3 -U.S., 2 -Sweden)
35 Machinery Except Electrical	3	• Milling and grinding (1 -Yugoslavia) • Spherical tool against vibrating rod (1 -U.S.) • Scale models of turbomachinery facility (1 -U.S.)

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

SIC/ Industry	Number of Publications	Areas of Publication
36 Electrical Machinery	None	
37 Transportation Equipment	None	
49 Utilities	18	• Fans for utility boilers (1 -Japan) • Switching room (1 -U.S.S.R.) • Power plant noise (4 -U.S.) • Valves for steam plants (1-U.S.) • Machinery noise sources (1 -U.S.) • Gas turbines (2 -U.S.) • New plant noise considerations (5 -1 -U.S., 2 -Netherlands, 2 -Germany) • Steam piping systems (3 -2 -U.S., 1 -England)
Mixed Category	27	Industrial Noise Sources • Identification and surveys (8 -2 -Germany, 2 -England, 2 -India, 2 -U.S.) • Noise criteria (2 -U.S.) • Plant noise control approaches (17 -13 -U.S., 1 -Canada, 1 -Germany, 1 -Belgium, 1 -France.)

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

SIC/ Industry	Number of Publications	Areas of Publication
Mixed Category (continued)	18	Noise Measurement Techniques o Machines in reverberation rooms (2 -U.S.) • Principles of preception and measurement (1 -France) • Plant noise measurement techniques (2 -U.S.) • Machine noise measurement techniques (12 -9 -U.S., 1 -U.S.S.R., 1 -Germany, 1 -France) • Errors in measurement of machine noise (1 -Germany)
	11	Noise Criteria and Standards • Community impact (4 -U.S.) • Standards (7 -1 -Canada, 1 -U.S.S.R., 1 -Austria, 1 -Sweden, 3 -U.S.)
	5	Analysis Techniques • Nomograms (1 -Germany) • Empirical (1 -Japan) • Dynamic analysis (3 -2 -U.S., 1 -Poland)
	15	Equipment, Mechanical • Conveyors (1 -Germany) • Compressors (7 -6 -U.S., 1 -Germany) • Gas turbines (3 -1 -U.S., 1 -Japan, 1 -England) • Lift truck (1 -U.S.) • Power tools (1 -U.S.) • Prime mover (1 -U.S.) • Dust collectors (1 -England)

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

SIC/ Industry	Number of Publications	Areas of Publication
Mixed Category (continued)	24	Equipment, "Pneumatic" • Fan Noise (8 - 5-U.S., 2-Japan, 1-Germany) • Combustion Noise (13 - 4-U.S., 1-U.S.S.R., 2-Germany, 6-England) • Noise from airflow through a grill (1-Japan) • Exhaust noise (2-U.S.)
	15	Equipment, Hydraulic • Pumps (5 - 3-Poland, 1-Hungary, 1-U.S.) • Valves (1-U.S.) • Piping systems (1-U.S.) • Water turbines (1-Tasmania) • Oil Cushion (1-Iran) • "Hydraulic equipment" (6 - 5-U.S., 1-England)
	10	Components • Gears (6 - 4-U.S., 1-Poland, 1-Japan) • Rotor (1-England) • Bearings (2-U.S.) • Clutch (1-U.S.)
	8	Vibration Isolation • Correlation of machine vibration and radiated noise (1-England) • Structural damping (1-U.S.) • Machinery foundations (1-U.S.) • Machine noise reduction (5 - 4-U.S., 1-U.S.S.R.)

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Concluded)

SIC/ Industry	Number of Publications	Areas of Publication
Mixed Category (continued)	16	Acoustical Treatment • Barriers and enclosures (6 - 5-U.S., 1-Germany) • Ducts and pipes (3-U.S.) • Fluid and electrical components (1-U.S.) • Laminated metal composites (1-U.S.) • Machines (5-U.S.)
	11	Heating, Ventilating and Air Conditioning • Air handling system (1-U.S.) • Residential air conditioner (1-U.S.) • Air conditioner cabinet (1-Germany) • Chiller (2-U.S.) • Cooling tower (1-Germany) • Circulating pump (1-France) • Unducted HVAC equipment (1-U.S.) • Duct systems (2-U.S.) • Fans (1-Germany)

APPENDIX E

INDUSTRIAL MACHINERY NOISE LEVELS

Machine types and noise levels were compiled by industry in order to identify:

- Machine types within each industry.
- Noise levels associated with each machine type.

Accordingly 357 machines, distributed over 20 industries, were identified. Bases for the identification were

- Department of Commerce reports of the 1972 Census of Manufacturers, Reference 5. These documents formed the primary basis of the machinery and industry distributions.
- References on machine noise (References 1, 3, 4, 8, 9, 10, 11, 12, 13) yielded both noise level data and information on machines used by industry. Machine types of the construction and utility industries were primarily gathered from these reports.

No attempt was made to be all inclusive in identifying machinery because much more data were readily available in some industries, such as the fabricated metal products industry, than in others, such as the tobacco manufacturers industry. Also, there are many species of some generic machine types which are of various manufacture and in various stages of useful life, with varying associated noise levels. The noise levels may also depend on the type of workpiece being handled. Therefore, a rigorous structure of the machine-noise level-industry matrix is very large and beyond the scope of this effort. The machinery noise level presented is an indicator rather than as an absolute value.

A search for machinery noise data indicated that most of the available data is in the form of A-weighted sound pressure levels (SPL). Little noise spectra data was found, with the exception of that in Reference 4.

Table E-1 is a summary of the machinery noise by industry. The complete machine-industry-noise level matrix is given in Tables E-2 to E-18. Table E-1 is a compilation of the SIC code for each industry, the industry, the number of machines identified with each industry, the number of machines for which SPL's were available, and the mean SPL for the

machines identified. The mean SPL is intended to serve as a gross indicator of the noise level of the machines in the industry and should not be taken as an indicator of the noise level of the industry (which must be related to the number of machines of each type within the industry and the typical plant acoustics).

Noise levels were identified for approximately 67 percent of the machines. This is a relatively high value primarily because many of the machines within the industries could not be readily identified during this effort and many of those machines which were identified were drawn from the noise measurement data base.

Mean SPL's for the machines range from 85 dBA for the leather and leather goods industry machines to 109 dBA for the construction industry machines. Most of the high mean SPL values (above 95 dBA) are associated with industries in which metal forming and cutting are the predominant operations. Noise levels of the petroleum and coal products industry machines are primarily the noise of the machines associated with mining operations.

Table E-1 SUMMARY OF MACHINE NOISE BY INDUSTRY

SIC Code	Industry	Number of Machines Identified	Number of Machines With SPL Data	Mean SPL for Machines, dBA (2 - 5 ft.) (.61-1.52 mtrs.)
16	Construction	36	19	(85)*
20	Food and Kindred Products	42	18	94
21	Tobacco Manufacturers	6	0	N.A.
22	Textile Mill Products	15	10	93
23	Apparel and Related Products		Included in SIC 22	
24	Lumber and Wood Products	15	11	96
25	Furniture and Fixtures		Included in SIC 24	
26	Paper and Allied Products	21	9	91
27	Printing, Publishing, & Allied Products	22	11	90
28	Chemical and Allied Products	15	15	88
29	Petroleum and Coal Products	29	7	99
30	Rubber and Misc. Plastic Products		Included in SIC 28	
31	Leather and Leather Goods	10	10	85
32	Stone, Clay and Glass Products	12	12	91
33	Primary Metal Industries	38	38	98

* 15.2 meters (50 feet)

Table E-1 SUMMARY OF MACHINE NOISE BY INDUSTRY (Concluded)

SIC Code	Industry	Number of Machines Identified	Number of Machines With SPL Data	Mean SPL for Machines, dBA (2 - 5 ft) (.61-1.52 mtrs)
34	Fabricated Metal Products	41	27	99
35	Machinery Except Electric	21	17	101
36	Electrical & Electronic Machinery	13	12	99
37	Transportation Equipment	13	12	99
49	Utilities	8	8	95
	TOTALS	357	236	-

Table E-2 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 16)

Industry	Machine	Overall Level dBA	Ref. No.
Construction Other Than Building Construction	Bulldozers	80*	8
	Scrapers	88*	8
	Trucks (Construction)	91*	8
	Pavers Self-Propelled	89*	8
	Backhoes	85*	8
	Compacters		
	Graders	85*	8
	Frontloaders	79*	8
	Shiploaders		
	Concrete Mixers	85*	8
	Conveyors		
	Vibrators	76*	8
	Concrete Pumps	82*	8
	Rock Crushers		
	Cranes	83*	8
	Pile Drivers	101*	8
	Drop Hammers		
	Pneumatic Tools	85*	8
	Off-Highway Tractors	80*	8

Table E-2 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 16)

Industry	Machine	Overall Level dBA	Ref. No.
Construction Other Than Building Construction	Draglines		
	Shovels		
	Street Sweeper		
	Rock Drill	98*	8
	Derrick	88*	8
	Clamshell		
	Ripper		
	Pipe Layer		
	Roller		
	Trencher		
	Fork Lift		
	Travel Lift		
	Compressor	81*	8
	Generator	78*	8
	Jack Hammer	88*	8
	Stripping Pump		
	Well-Point Pump		

* SPL Measured at 15.2 meters (50 feet) from machine.

Table E-3 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 20)

Industry	Machine	Overall Level dBA	Ref. No.
Food and Kindred Products	Bottling & Packaging Machinery	93	9
	Washing & Sterilizing Equipment		
	Pasteurizers		
	Homogenizers	93**	9
	Ice Cream Freezers		
	Butter & Cheese Processing Machinery		
	Dry Milk Processing Machinery		
	Slicers		
	Choppers	92*	4
	Grinders		
	Dicers		
	Mixers		
	Tenderizers		
	Ovens		
	Continuous Bread-Making Equipment		
	Wrapping Machines		
	Bottling Equipment		
	Meat & Poultry Processing Equipment		

Table E-3 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Cont'd)
(SIC Code 20)

Industry	Machine	Overall Level dBA	Ref. No.
Food and Kindred Products	Fruit & Vegetable Canning Machinery		
	Flour & Grainmill Machinery		
	Sugar Plant Machinery		
	Oilseed Crushing & Extract. Machinery		
	Bottle Washers & Sterilizers	93**	9
	Uncasers & Casers		
	Capping Machines		
	Packing & Packaging Machines		
	Carbonators		
	Filling & Labeling Machines		
	Molding Machine	86*	4
	Peanut Blanching Machine	85*	4
	Bottle Fillers	96**	9
	Lift Truck	91**	9
	Peanut Sizing Machine	95**	9
	Salt Pulverizor	95*	9

Table E-3 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 20)

Industry	Machine	Overall Level dBA	Ref. No.
Food and Kindred Products	Vibrating Conveyor	91**	9
	Metal Conveyor for Bottles	94**	9
	Pecan Shell Cracker	101**	9
	Paper Container Shear	100**	9
	Candy Cane Twister	95**	9
	Wash Tank	100**	9
	Refrigeration Compressor	100**	9
	Candy Print Machine	99**	9

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.
** SPL measurement distance not specified.

Table E-4 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 21)

Industry	Machine	Overall Level dBA
Tobacco Manufacturers	Conveyors	
	Driers	
	Fans	
	Cutting Equipment	
	Washing Equipment	
	Packaging Equipment	

Table E-5 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 22)

Industry	Machine	Overall Level dBA	Ref. No.
Textile Mill Products (Includes apparel and other finished products, SIC 23).	Cleaning & Opening Machinery		
	Carding & Combing Machines		
	Drawing & Roving Frames		
	Spinning Frames	82*	4
	Twisting Frames	83*	4
	Yarn Preparing Machines	97*	4
	Power Looms	102*	4
	Knitting Machines		
	Bleaching, Dyeing & Finishing Machinery	100**	4
	Drying Machinery		
	Reducing Machines	96*	4
	Reducer Transfer Machines	89*	4
	Combing Machines	95*	4
	Pin Drafters	92*	4
	Preparers	90*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.
** SPL measurement distance not specified.

Table E-6 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 24)

Industry	Machine	Overall Level dBA	Ref. No.
Lumber and Wood Products (Includes furniture & Fixtures, SIC 25)	Veneer & Plywood-Making Machinery		
	Saws	111*	4
	Jointers	88*	4
	Matchers		
	Molders	99*	4
	Mortisers		
	Shapers	89*	4
	Tenoners	95*	4
	Lathes	98*	4
	Planing Machines	108*	4
	Surfacing Machines	98*	4
	Drills		
	Barkers	91*	4
	Slashers	97*	4
	Sanders	85*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-7 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 26)

Industry	Machine	Overall Level dBA	Ref. No.
Paper and Allied Products	Barkers	91*	4
	Chippers		
	Knotters		
	Splitters		
	Chipscreens		
	Grinders		
	Deckers		
	Digesters		
	Beaters		
	Jordans		
	Calenders	93*	4
	Fourdriniers		
	Bagmaking Machines		
	Corrugated Box Making Machines	97*	4
	Box, Carton & Shipping Container Making Mach.	85*	4
	Toilet Roll and Napkin Making Machines		
	Slashers	97*	4
	Pulp Preparation Machine	82*	4
	Mixers	94*	4
	Paper Machines	88*	4
	Pumps	92*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-8 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 27)

Industry	Machine	Overall Level dBA	Ref. No.
Printing, Publishing & Allied Products	Lithographic Printing Presses		
	Newspaper Presses	92*	4
	Business Form Presses		
	Commercial Presses		
	Gravure		
	Flexographic		
	Typesetting Machinery	81*	4
	Saddle Binding Equipment		
	Perfect & Hard Case Binding Equipment		
	Electrotyping Machines		
	Stereotyping Machines		
	Paper Cutting Machines		
	Collating Machines	90*	4
	Gathering Machines		
	Printer-Slotters	98*	4
	Stitchers	85*	4
	Folders	94*	4
	Shears	103*	4
	Ink Mills	91*	4
	Cleaning Tanks	87*	4
	Newsprint Rewinders	85*	4
	Air Ejectors	83*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-9 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 28)

Industry	Machine	Overall Level dBA	Ref. No.
Chemical and Allied Products (Includes rubber & misc. plastic products, SIC 30)	Ink Mills	93*	4
	Pigment Mills	91*	4
	Pebble Mills	80*	4
	Mixers	80*	4
	Drum Cleaners	78*	4
	Five-Roll Mills	97*	4
	Hammer Mills	98*	4
	Compounding Rolls	92*	4
	Ball Mills	99*	4
	Fabric Coaters	81*	4
	Rewind, Fabric Beaming	80*	4
	Rotary Kilns	82*	4
	Rubber Mills	86*	4
	Tread Tubers	90*	4
	Curing Presses	94*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-10 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 29)

Industry	Machine	Overall Level dBA	Ref. No.
Petroleum and Coal Product	Rotary Drilling Surface Equipment		
	Rotary Drilling Subsurface Equipment		
	Cable Tool Drilling Machinery		
	Flowing Well Equipment		
	Rod Lifting Machinery		
	Pumping Units		
	Oil & Gas Separating, Metering & Treating Equipment		
	Well Surveying Machinery		
	Crushing, Pulverizing & Screening Machinery	86**	10
	Drills	110**	10
	Cutting Machines	96*	12
	Longwall Mining Machines		
	Gathering Arm Loading Machines	99*	12
	Slusher Hoists Loading Machines		
	Continuous Mining Machines	97*	12
	Borers		
	Rippers		

Table E-10 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)

Industry	Machine	Overall Level dBA	Ref. No.
Petroleum and Coal Product	Shuttle Cars	93* (Loading)	12
	Mine Cars		
	Flotation Machines		
	Wet Cyclones		
	Centrifugal Driers		
	Scrubbers		
	Thermal Driers		
	Feeders		
	Grinding Mills		
	Screens		
	Shakers		
	Roof Bolter	112*	11

* SPL measured within .914 meters (3 feet).

** SPL measurement distance not specified.

Table E-11 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 31)

Industry	Machine	Overall Level dBA	Ref. No.
Leather & Leather Products	Fleshing Machines	89*	4
	Hair Driers	88*	4
	Lime Mixing Tubs	77*	4
	Setting Out Machines	103*	4
	Splitting Machines	85*	4
	Coloring Drums	90*	4
	Plating	81*	4
	Seasoning Machines	80*	4
	Spraying Machines	78*	4
	Measuring Machines	77*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-12 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 32)

Industry	Machine	Overall Level dBA	Ref. No.
Stone, Clay & Glass Products	Clay Crushers	92*	4
	Clay Till Extrusion Machines	82*	4
	Packing Machines	86*	4
	Bottle Forming Machines	98*	4
	Mixers	93*	4
	Pneumatic Chippers	84*	4
	Cut Off Saws	89*	4
	Stone Planers	98*	4
	Cranes	84*	4
	Stone Saws	99*	4
	Concrete Aggregate	89*	4
	Clay Tile Kiln (Unloading)	97*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-13 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 33)

Industry	Machine	Overall Level dBA	Ref. No.
Primary Metal Industries	Grinders	90*	4
	Pneumatic Chippers	117*	4
	Furnaces (Ingot Heating)	93*	4
	Furnaces (Oil Heating)	93*	4
	Wood Planers	107*	4
	Friction Saws	107*	4
	Shake Outs	103*	4
	Pneumatic Rams	84*	4
	Tumblers	99*	4
	Push Up Machines	99*	4
	Core Blowers	116*	4
	Core Draw Vibrators	108*	4
	Air Hoists	108*	4
	Electric Furnaces	96*	4
	Sand Slingers	96*	4
	Jolt Squeeze Machines	97*	4
	Crucible Heaters	81*	4
	Roughing Mills	102*	4
	Levelers	90*	4
	Decoilers	116*	4
	Anealing Furnaces	93*	4
	Lectromelt Furnaces	95*	4
	Open Hearth Furnaces	80*	4

Table E-13 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 33)

Industry	Machine	Overall Level dBA	Ref. No.
Primary Metal Industries	Scarfing Equipment	36*	4
	Bloomer Mills	90*	4
	Strip Mills	97*	4
	Conveyors	98*	4
	Forging Hammers	109*	4
	Coke Ovens	93**	1
	Sinter Plants	100**	1
	Blast Furnaces	93**	1
	Basic Oxygen Furnaces	95**	1
	Soaking Pits	98**	1
	Rolling Mills	95**	1
	Continuous Picklers	95**	1
	Pipe Mills	96**	1
	Wire Drawing	95**	1
	Nail Mills	98**	1

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not identified.

Table E-14 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 34)

Industry	Machine	Overall Level dBA	Ref. No.
Fabricated Metals Product	Boring Machines	97*	4
	Drilling Machines	98*	4
	Gear-Cutting Machines	88*	4
	Grinding Machines	106*	4
	Polishing Machines	95*	4
	Lathes	107*	4
	Milling Machines	89*	4
	Saws	107*	4
	Broaching Machines		
	Planers		
	Shapers	93*	4
	Cut Off Machines	103*	4
	Tapping Machines	94*	4
	Threading Machines		
	Automatic Chucking Lathes		
	Screw Machines	90*	4
	Station & Transfer Machines		
	Electric Discharge Machines		
	Electrochemical Machines		
	Honing & Lapping Machines		
	Welding Machines	82*	4

Table E-14 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 34)

Industry	Machine	Overall Level dBA	Ref. No.
Fabricated Metals Product	Punches	98*	4
	Shears	93*	4
	Bending Machines	92*	4
	Forming Machines	108*	4
	Mechanical Presses	107*	4
	Hydraulic Presses		
	Pneumatic Presses	101*	4
	Extrusion Presses		
	Headers & Upsetters	106*	4
	Swaging Machines		
	Gear & Spline Rolling Machines	89*	4
	Thread Rolling Machines	89*	4
	Marking Machines		
	Riveting Machines	117*	4
	Die Casting Machines		
	Impact Wrenches		
	Power Driven Hand Tools	95**	4
	Drop Hammers	111*	4
	Sand Blast Machines	121*	4
	Vibrators	104*	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-15 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 35)

Industry	Machine	Overall Level dBA	Ref. No.
Machinery, Except Electric	Milling Machines	89*	4
	Boring Machines	97*	4
	Pneumatic Presses	101*	4
	Hob Grinders	89*	4
	Multiple Drills	96*	4
	Turret Lathes	107*	4
	Welders	112*	4
	Riveting Machines	125*	4
	Chippers	127*	4
	Grinders	95*	4
	Shears	94*	4
	Punch Press	99**	4
	Drilling Machines	98*	4
	Gear-Cutting Machines	89*	4
	Lapping, Polishing & Buffing Machines		
	Broaching Machines		
	Planers		
	Shapers	93*	4
	Tapping Machines	94*	4
	Saws	107*	4
	Thread Machines		

* SPL measure .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-16 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 36)

Industry	Machine	Overall Level dBA	Ref. No.
Electrical and Electronic Machinery	Drilling Machines	98*	4
	Grinding Machines	106*	4
	Polishing Machines	95*	4
	Saws	107*	4
	Tapping Machines	94*	4
	Threading Machines		
	Welding Machines	82*	4
	Punches	98*	4
	Shears	93*	4
	Bending Machines	92*	4
	Forming Machines	108*	4
	Riveting Machines	117*	4
	Power Driven Hand Tools	102**	4

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-17 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 37)

Industry	Machine	Overall Level dBA	Ref. No.
Transportation Equipment	Riveting Machines	133*	4
	Drills	88*	4
	Saws	107*	4
	Routers	86*	4
	Welding Machines	82*	4
	Punches	98*	4
	Shears	93*	4
	Bending Machines	92*	4
	Forming Machines	108*	4
	Mechanical Presses	101*	4
	Hydraulic Presses		
	Pneumatic Presses	101*	4
	Impact Wrenches		
	Power Driven Hand Tools	95**	13

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-18 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 49)

Industry	Machine	Overall Level dBA	Ref. No.
Utilities	Fans	110**	3
	Gas Turbines	90**	3
	Oil Burners	85**	3
	Diesel Engines	100**	3
	Rotary Blowers	120**	3
	Turbo-Alternators	85**	3
	Feed Pumps	90**	3
	Transformers	60-100** (size dependent)	3

** Noise measurement distance not specified.

APPENDIX F

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